LOCOMOTIVE EXHAUST EMISSIONS TECHNOLOGY NEEDS EPA EXHAUST EMISSIONS REGULATORY IMPACTS

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The U.S. Environmental Protection Agency is close to finalizing rules for locomotive emissions that will affect nearly all locomotives owned by the major railroads after the year 2000. Not only will the OEMs have to meet typical mobile source standards on their newly manufactured engines; but the railroads will have to retrofit most of their existing fleets to meet emissions limits that reduce oxides of nitrogen by approximately 35% from the current unregulated fleet.

The proposed rule (A Notice of Proposed Rulemaking or NPRM was published by EPA on January 31, 1997) would have an immediate impact on locomotive engine manufacturers as well as almost everyone who performs heavy overhauls on locomotive engines. These engines will then have to be maintained properly throughout their lives. Proper maintenance will not necessarily be defined by the locomotive operator — a railroad — but by whoever holds the EPA certificate on the engine family.

The proposed rule would separate locomotives into four groups:

- "Tier 0" where the engine was originally manufactured from January 1, 1973 through December 31, 2001
- "Tier I" where the engine was originally manufactured from January 1, 2002 through December 31, 2004
- "Tier II" where the engine was originally manufactured on January 1, 2005 or later
- Pre-Tier 0 engines, which are not covered by the rule unless the owner upgrades them to Tier 0 standards

The proposed gaseous and particulate matter emisssions standards for Tiers 0, 1, and II are given in Table 1, with weighting factors for determining the emissions level shown in Table 2. Every locomotive must meet both the line-haul and switcher standards. Passenger locomotives would be weighted differently than freight locomotives, as shown. Smoke standards are given in Table 3. EPA developed these standards by calculating reductions in oxides of nitrogen (NO_x) of 33%, 45% and 60% respectively for Tiers 0, I, and II compared to mid 1990s national fleet averages. Tiers I and II have some tightening of particulate matter, hydrocarbons, and carbon-dioxide compared to the baseline, while Tier 0 locomotives do not have to make any reductions in these emittants. The smoke standards are similar to those for truck and off-highway engines.

It seems likely that OEMs and other suppliers will be able to develop kits to meet the retrofit needs. Further it is likely that the OEMs will have little difficulty meeting the new engine Tier I standards that will go into effect in 2002. The Phase II standards that go into effect January 1, 2005 are where the challenge arises. The Phase II limits include 5.5 g/hp-hr NO_x and 0.2 g/hp-hr particulate matter. While onhighway engines will be meeting more stringent standards before 2005, those engines are installed in vehicles which have an order of-magnitude smaller power density and considerably more air cooling potential than locomotives have. Both EPA and the OEMs believe that present technology will only bring locomotive engines down to approximately 6.5 g/hp-hr NO_x. Also, the test procedure for on-highway engines is quite different from the proposed locomotive test procedure. While it is difficult to compare the two tests, in general the locomotive test procedure is more stringent.

Besides high power density and limited cooling potential, locomotive engines have tight overhead clearances which limit stack lengths to mere inches leave little room for exhaust treatment devices. This does not mean that exhaust

treatment cannot be done; but considerable engineering would be necessary to make it fit.

We expect the OEMs to use the normal bag of tricks on engine design features to meet emissions limits, especially for the "Phase I" standards. Improved fuel injection systems tied to electronic engine control is probably the key to any future engine design. The turbocharging will likely be improved upon to match the engine's needed fuel-air mixture needs better, while intercooler-aftercooler equipment will be further refined from today's levels to lower the inlet air temperature.

The locomotive regulations will allow the higher sulfur off-highway fuel that railroads currently use. So, the OEMs need to plan for approximately 0.2% sulfur in the fuel while meeting the 0.2 g/hp-hr particulate limit.

EPA recognized that some engine models may not make the standards without massive redesign that would be unreasonably expensive, so they proposed that manufacturers can average, bank, and trade emissions credits to meet the standards on a fleet-wise basis. This could be especially useful for Tier 0 locomotives that were never designed to meet any emissions standards and which are all over the map on their baseline emissions levels. "Banking" means that a manufacturer can earn a credit for having an engine family under the emissions limits in one year and hold those credits for up to 3 years and then offset any engine family that exceed the limits. "Trading" allows manufacturers to give their credits to other manufacturers. Compensation is set by the marketplace and is of no concern to EPA.

Locomotives will have to be "remanufactured" (using a certified "kit") at the time that the owner performs an overhaul on the diesel engine. For Tier 0, this will go into effect on January 1, 2000 for locomotives originally manufactured starting on January 1, 1994 and January 1, 2002 for locomotives originally manufactured from 1973 through 1993. No owner is required to do these remanufacturing events any sooner than he would normally perform an overhaul. EPA expects that nearly all linehaul locomotives will be remanufactured by the end of 2006. Switchers will take much longer, though no one knows today how long it will take to bring all of them into compliance.

Any entity that wishes to may obtain a certificate. The likely cast of certificate holders (EPA calls them "remanufacturers") will include the OEMs (General Electric Transportation Systems, General Motors Locomotive Group, and Caterpillar); some aftermarket suppliers; some non-railroad, non-OEM locomotive engine rebuilders; and possibly one or more railroads. The certificate basically covers an engine family that the remanufacturer defines by engine specifications and that has a certified level of emissions determined through an EPA "Federal Test Procedure" or FTP. The remanufacturer defines a "kit" that is installed in the engine family by an installer at the time of a top-end overhaul. The installer may be a railroad, the remanufacturer, or a third party engine shop. While we expect that the installer will not have to hold the EPA certificate, he must obtain the use of it for every Tier 0 and later engine he overhauls starting in 2000.

What will constitute a "kit" could vary quite a bit. It must include installation instructions and instructions for inspection, maintenance, and repairs for the life of the engine. Some kits may include parts, while others may include specific parts lists for the installer to buy. Other remanufacturers may take a less specific approach to the parts and leave it to the installer to select parts and components that meet performance parameters or there may be a list of acceptable parts from different suppliers. The marketplace will determine the contents of kits. Installers can expect to pay something to remanufacturers for the license to use the certified kits. Again, the marketplace will determine the price. Remanufacturers will spend hundreds of thousands of dollars per engine family to develop and certify their kits and they will assume considerable liability for auditing installers, conducting in-use testing of the engines, and solving any in-use problems that are identified by in-use tests. So a remanufacturer will expect to recover that investment either in license fees or in the sale of parts.

EPA's NPRM includes an estimate that the incremental cost of the license, parts, and labor

for Tier 0 remanufacturing will be approximately $80,000 per locomotive. This is a cost that would be incurred at the time of an engine overhaul and assumes the incremental is above and beyond what it would cost to replace all of the engine power assemblies and fuel injectors and resetting of engine timing. For the engines that will be built new to meet the Tier II standards, EPA estimates that there will be no incremental cost passed on to the railroads.

EPA didn't give much documentation of how they reached the $80,000 and $0 figures, citing proprietary information obtained from the OEMs. In extreme examples, some "kits" may involve nothing more than resetting fuel injection timing at the time of a heavy overhaul while others could entail replacing mechanical engine governors and fuel injection equipment with electronically controlled equipment; rematching turbochargers; changing the design of pistons, cylinder liners, and heads; adding additional radiators; and repiping the entire cooling system. Even without a license fee, the latter kit would result in an incremental cost well over $80,000, while the former kit would cost nothing at the time of an overhaul other than the license fee.

Remanufacturers will have to conduct market research to determine what the railroads want in these kits. An option is to make a fairly advanced technology kit that does not cause any fuel penalty and that improves engine performance and reliability. Such a kit would cost more, but presumably it would have a positive rate-of-return on the investment. Another option for the same engine family might be an inexpensive kit that causes a fuel penalty and does nothing to improve performance and reliability.

At about three-quarters of what EPA calls the "useful life" of engines, the manufacturers/ remanufacturers will be required to conduct in-use FTP emissions tests of a small sample of engines. If the engines do not exceed the emissions levels that the remanufacturer specified in his certification, the engines "pass" the test. If they exceed those levels, the remanufacturer must determine the reason for it. If the reason is because the owner or operator of the locomotive did not follow the remanufacturer's inspection, maintenance, and repairs recommendations, the remanufacturer is not liable for the results (and neither is the owner/operator, as long as he used reasonable judgement in maintaining his locomotive). If the problem is due to the design of the kit or a part or to workmanship of a part or component, the remanufacturer must develop a fix for the problem. These fixes would be agreed upon between the remanufacturer and EPA and would be provided to the railroads with the expectation that the fixes would be done during regularly scheduled maintenance. EPA has not proposed mandatory recalls with locomotives taken out of service.

Useful life was defined as 7.5 times the horsepower rating to obtain megaWatt-hours. A 4000 horsepower locomotive would have a useful life of 30,000 megaWatt-hours. Three quarters of that would be 22,500 megaWatt-hours. For Tier 0 locomotives lacking Watt-hour meters, the useful life would be 750,000 miles.

There is an "antitampering" provision in the NPRM that is common to all EPA rules. If a railroad or other engine maintainer knowingly changes the emissions characteristics of the engine (through changes in engine set-up, removing emissions control devices, or replacing a part with another part known to alter the emis-sions characteristics), the maintainer has com-mitted a Federal crime. The civil penalties were not spelled out in the NPRM, but will probably be the same as for other mobile sources.

The anti-tampering provision and the remanufacturer's maintenance instructions will change locomotive maintenance. These rules apply to newly manufactured locomotive engines too.

The certificate holders will provide recommended inspection and maintenance intervals and will recommend what specific parts should be replaced or requalified at these intervals. The NPRM does not say that the railroad or other engine maintainer must follow those recommendations exactly. The railroad or maintainer may use its own experienced judgement, as they do today. Unacceptable maintenance is knowingly installing parts that affect the emissions level. That would include parts that might even "improve" emissions.

TABLE 1. SUMMARY OF EPA PROPOSED LOCOMOTIVE EMISSIONS LIMITS
(Units are grams per brake horsepower-hour)

Type of Service:	Line-Haul Duty Cycle			Switcher Duty Cycle		
Year Originally Built:	1973-99	2000-04	2005-??	1973-99	2000-04	2005-??
Tier:	0	I	II	0	I	II
Hydrocarbons HC	1.0	0.55	0.3	2.1	1.2	0.6
Carbon Monoxide CO	5.0	2.2	1.5	8.0	2.5	2.4
Oxides of Nitrogen Nox	9.5	7.4	5.5	14.0	11.0	8.1
Particulate Matter PM	0.6	0.45	0.2	0.72	0.54	0.24

Notes:
1. These are the limits for engines operating on diesel fuel oil. Different limits are proposed for CO from natural gas engines. Aldehyde limits are proposed for alcohol-fueled engines.
2. EPA has proposed individual throttle position limits for each emittant in addition to the duty cycle weighted limits.

TABLE 2. EPA PROPOSED ENGINE DUTY CYCLES FOR CERTIFICATION

Duty Cycle:	Freight	Passenger	Switcher
Throttle Notch			
Idle	38.0	47.4	59.8%
1	6.5	7.0	12.4
2	6.5	5.1	12.3
3	5.2	5.7	5.8
4	4.4	4.7	3.6
5	3.8	4.0	3.6
6	3.9	2.9	1.5
7	3.0	1.4	0.2
8	16.2	15.6	0.8
Dynamic Brake	12.5	6.2	0.0

TABLE 3. SMOKE STANDARDS[1]
(Units are % Opacity)

Number of stacks	Exhaust Diameter	Examined Plume Section	Steady-State	30-sec Peak	3-sec Peak
Single	12" or less	Total	20	35	50
	More than 12"	Each 6" Segment, or	10	15	20
		Total[2]	30	40	55
Multiple	12" or less	Any One	20	35	50
		Sum of Stacks	30	40	55
	More than 12"	Each 6" Segment, or	10	15	20
		Total for any One	30	40	55
		Sum of Stacks	40	50	60