

temperatures from flammable materials such as dust. One approach would be the use of air-gapped exhaust systems (*i.e.*, an exhaust pipe inside another concentric exhaust pipe separated by an air-gap) that serve to insulate the inner high temperature surface from the outer surface which could come into contact with the dust. The use of such a system may be additionally desirable in order to maintain higher exhaust temperatures inside the catalyst in order to promote better catalyst function. Another technology to control surface temperature already used by some nonroad equipment manufacturers is water cooled exhaust systems.¹⁷³ This approach is similar to the air-gapped system but uses engine coolant water to actively cool the exhaust system. We do not believe that flammable dust concerns will prevent the use of either a NO_x adsorber or a CDPF because catalyst temperatures are not expected to be unacceptably high and because remediation technologies exist to address these concerns. In fact, exhaust emission control technologies (*i.e.*, aftertreatment) have already been applied on both an OEM basis and for retrofit to nonroad equipment for use in potentially explosive environments. Many of these applications must undergo Underwriters Laboratory (UL) approval before they can be used.¹⁷⁴

Nonroad engines greater than 750 hp are unique in that they do not have direct highway equivalents. However, this does not mean that unique catalyst based emission control technologies need to be developed separately for these larger applications. Rather, larger engines can, and do in retrofit applications today, use multiple catalyst systems in a parallel configuration. As an example, a highway 12 liter displacement in-line six cylinder engine might use a single 18 liter CDPF, while a nonroad 24 liter displacement V12 cylinder (a vee engine has two rows of cylinders set at an angle to each other) engine would use two 18 liter CDPFs, one for each bank of the vee engine. Using two smaller catalysts in place of one larger catalyst can be easier to package and may allow for close coupling of the catalyst technology to the turbocharger exhaust outlet to

improve temperature management in some applications. Today, many passenger cars and light-duty trucks with V6 or V8 engines use individual catalysts for each engine bank to improve packaging and better manage temperatures.

We agree that nonroad equipment must be designed to address durable performance for a wide range of operating conditions and applications that would not commonly be experienced by highway vehicles. We believe further as demonstrated by retrofit experiences around the world that technical solutions exist which allow catalyst-based emission control technologies to be applied to nonroad equipment.

3. Are the Standards Proposed for Engines of 75 hp or Higher Feasible?

There are three primary test provisions and associated standards in the Tier 4 program we are proposing today. These are the proposed Nonroad Transient Cycle (NRTC), the existing ISO C1 steady-state cycle, and the proposed highway based Not-To-Exceed (NTE) provisions. A nonroad diesel engine meeting the proposed standards for each of these three test cycles would be lawful for use in any kind of nonroad equipment. Additionally, we have alternative optional test cycles including the proposed Constant Speed Variable Load (CSVL) cycle, the existing ISO-D2 steady-state cycle and the proposed Transportation Refrigeration Unit (TRU) cycle which a manufacturer can choose to use for certification provided that the manufacturer can demonstrate to the Agency that the engine will only be used in a limited range of nonroad equipment with specifically defined operating conditions. Compliance on the proposed transient test cycles includes weighting the results from a cold start and hot start test with the cold start emissions weighted at 1/10 and hot start emissions weighted at 9/10. A complete discussion of these various test cycles can be found in chapter 4.2 and 4.3 of the draft RIA.

The standards proposed today for nonroad engines with rated power greater than or equal to 75 horsepower are based upon the technologies and standards for highway diesel engines which go into effect in 2007. As explained above, we believe these technologies, namely NO_x adsorbers and catalyzed diesel particulate filters enabled by 15 ppm sulfur diesel fuel, can be applied to nonroad diesel engines in a similar manner as for highway diesel engines. We acknowledge that there are additional constraints on nonroad diesel engines

which must be considered in setting these standards, and we have addressed those issues by allowing for additional lead time or slightly less stringent standards for nonroad diesel engines in comparison to highway diesel engines (and likewise have made appropriate cost estimates to account for the technology and engineering needed to address these constraints).

We have proposed a PM standard for engines in this category of 0.01 g/bhp-hr based upon the emissions reductions possible through the application of a CDPF and 15 ppm sulfur diesel fuel. This is the same emissions level as for highway diesel engines in the HD2007 program. While baseline soot (the solid carbon fraction of PM) emission levels may be somewhat higher for some nonroad engines when compared to highway engines, these emissions are virtually eliminated (reduced by 99 percent) by the CDPF technology. As discussed previously, the baseline (engine-out) SOF emissions levels may also need to be reduced through the application of modern piston ring pack designs and valve stem seals. With application of the CDPF technology, the SOF portion of diesel PM is predicted to be all but eliminated. The primary emissions from a CDPF equipped engine are sulfate PM emissions formed from sulfur in diesel fuel. The emissions rate for sulfate PM is determined primarily by the sulfur level of the diesel fuel and the rate of fuel consumption. With the 15 ppm sulfur diesel fuel the PM emissions level from a CDPF equipped nonroad diesel engine will be similar to the emissions rate of a comparable highway diesel engine. Therefore, the 0.01 g/bhp-hr emission level is feasible for nonroad engines tested on the NRTC cycle and on the steady-state cycles, C1 and D2. Put another way, control of PM using CDPF technology is essentially independent of duty cycle given active catalyst technology (for reliable regeneration and SOF oxidation), adequate control of temperature (for reliable regeneration) and low sulfur diesel fuel (for reliable regeneration and low PM emissions).

The most challenging PM emissions control conditions for a CDPF are encountered under high engine load operation where high exhaust temperatures promote conversion of sulfur in diesel fuel to sulfate PM emissions. Under these high load conditions, soot and SOF oxidation rates will be very high and control of those portions of PM emissions will be highly effective. Sulfate PM emissions, however, will be higher than for other operating conditions. In a worst case scenario, where all of the sulfur is

¹⁷³ "Engine Technology and Application Aspects for Earthmoving Machines and Mobile Cranes, Dr. E. Brucker, Liebherr Machines Bulle, SA, AVL International Commercial Powertrain Conference, October 2001. Copy available in EPA Air Docket A-2001-28, Docket Item # II-A-12.

¹⁷⁴ Phone conversation with Manufacturers of Emission Control Association (MECA), 9 April, 2003 confirming the use of emission control technologies on nonroad equipment used in coal mines, refineries, and other locations where explosion proofing may be required.