Nitrous oxide emissions from a medium-duty diesel truck exhaust system

Christine K. Lambert*, Douglas Dobson, Christine Gierczak, Gang Guo, Justin Ura and James Warner
Ford Motor Company, Dearborn, MI 48121 USA
**corresponding author: clamber9@ford.com*

Introduction

Starting in 2010, medium-duty diesel trucks in the U.S. were introduced with aftertreatment systems that contained precious metal oxidation catalysts, soot filters, and Selective Catalytic Reduction (SCR) systems for control of nitrogen oxides (NO, NO_2). While modern diesel aftertreatment systems have high performance for meeting hydrocarbons, carbon monoxide (CO), NOx, and particulate matter, there is some concern over emission of nitrous oxide (N_2O) that can be formed within the exhaust system. N_2O has an atmospheric lifetime of approximately 114 years and is 298 times more effective than CO_2 at trapping heat in the atmosphere. In this study, the sources of N_2O are compared in the laboratory flow reactor and at the system level on diesel trucks. The interactions of HC with NOx on the DOC and NOx with NH_3 within the SCR catalyst were the predominant mechanisms for N_2O formation. The composite N_2O mass emission was calculated to be approximately 43 mg/mi, resulting in an equivalent CO_2 penalty of about 2%, similar to the 1-3% penalty estimated for the global light-duty vehicle fleet [1].

Materials and Methods

For commercial Pd-rich DOC performance evaluations, a pulsating-combusting reactor (pulsator) was used. A complete description of the experimental setup may be found elsewhere (Hepburn et al., 1996). The SCR activity data were obtained on a lab scale flow reactor using a commercial Cu/CHA introduced into the U.S. market in 2010 (Bull et al., 2009). Experimental work was performed on silicon carbide (SiC) filter cores obtained from a major commercial substrate manufacturer and a major autocatalyst coater. A 2011MY test vehicle was tested at 9500 lbs and equipped with a production 6.7L diesel engine and a LEVII catalyst system described in **Figure 1**. The engine had common-rail fuel injection, inter-cooled EGR and a dual turbocharger. The catalysts were aged as a system to an equivalent of 120,000 mi on an engine dynamometer with a 6.4L diesel engine.

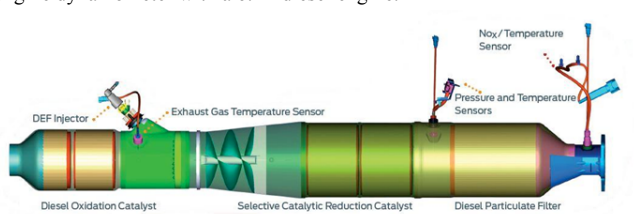

Figure 1. A modern diesel exhaust catalyst system used on 2010 medium-duty diesel trucks. [2]. DEF = diesel exhaust fluid (aqueous urea).

Results and Discussion

N_2O could be formed via the following reactions within the diesel catalyst system:

DOC:	$HC + O_2 \rightarrow CO_2, H_2O$	[1]
SCR:	$NH_4NO_3 \rightarrow \underline{N_2O} + 2H_2O$	[2]
SCR:	$2NH_3 + 2NO_2 \rightarrow \underline{N_2O} + N_2 + 3H_2O$	[3]
SCR:	$2NH_3 + 2O_2 \rightarrow \underline{N_2O} + 3H_2O$	[4]
DPF:	$2NH_3 + 2O_2 \rightarrow \underline{N_2O} + 3H_2O$	[5]

The final N_2O average emissions per cycle are summarized in **Table 1**, with the composite weighted N_2O calculated from 55% FTP-75 (light-duty federal test procedure) and 45% HWFET (highway fuel economy test). The FTP-75 test with filter regeneration resulted in little or no N_2O, so the amortized amount of 55 mg/mi was lower than a normal FTP-75.

Table 1. Composite N_2O mass (55% FTP-75 and 45% HWFET). The composite weighted legal limit for N_2O from medium-duty vehicles will be 50 mg/mi starting with the 2014 MY.

	FTP-75	**FTP-75 w/regen**	**HWFET**	**Composite Weighted**	**CO_2 equivalence**
N_2O (mg/mi)	56	55	29	43	12814

The interactions of HC with NOx on the DOC and NO_2 with NH_3 within the SCR catalyst were the predominant mechanisms for N_2O formation. There was no significant NO_2 production by the DOCs nor was there any significant ammonia oxidation by either the SCR catalyst or the filter that would lead to additional system N_2O creation. Bulk ammonium nitrate decomposition was not considered to be important.

Significance

The formation of N_2O was minimized through the use of low-loaded, Pd-rich DOCs and Cu/CHA SCR catalysts. The exhaust gas temperature window was either low (200-300°C) during city/highway driving or high (600°C) during filter regeneration.

References

1. Lambert, C., Dobson, D., Gierczak, C., Guo, G., Ura, J. and Warner, J. (2014) 'Nitrous oxide emissions from a medium-duty diesel truck exhaust system', *Int. J. Powertrains*, Vol. 3, No. 1, pp.4–25.
2. *Diesel Engine Aftertreatment: How Ford Knocks Out the NOx.* (2011) [online] Available at http://media.ford.com/images/10031/SD_Diesel_Aftertreatment.pdf (Accessed 5 April 2012).