ALPHA-GAMMA
TECHNOLOGIES, INC.

MEMORANDUM

DATE: June 9, 2005

SUBJECT: Cost per Ton for NSPS for Stationary CI ICE

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The purpose of this memorandum is to estimate the cost per ton of pollutant removed for the proposed new source performance standards (NSPS) for stationary compression ignition (CI) internal combustion engines (ICE). This memorandum also presents the cost per ton of other control technologies EPA considered.

Introduction

The proposed rule requires stationary CI engines to comply with standards that have been promulgated for nonroad CI engines. These standards consist of various tiered levels that increase in stringency. Although the proposed rule requires stationary CI engines to meet all tiers, EPA expects that stationary CI engines would generally emit the same levels as nonroad engines until Tier 4 is required, even in the absence of the rule. For the purpose of estimating reductions for stationary CI engines, the EPA does not take credit for reductions until Tier 4 is in effect. This means that the baseline level for estimating reductions is the tier level prior to Tier 4. The EPA expects that nitrogen oxides (NO_x) adsorbers and catalyzed diesel particulate filters (CDPF) will be used to meet Tier 4 levels and are expected to reduce NO_x and particulate matter (PM) emissions, respectively, by at least 90 percent.

Control Cost

The methodology for estimating the cost of these control technologies is presented in the memorandum entitled “Control Costs for NO_x adsorbers and CDPF for CI Engines,” included in the docket (Docket ID No. OAR-2005-0029). The average annual cost of control for NO_x adsorbers and CDPF were each estimated at $1 per horsepower (HP). The combined annual cost of control was estimated at $2/HP. To determine the annual control cost per engine, EPA multiplied the combined annual cost of control by the average engine size for each HP range. The total annual cost of control per engine for each engine size range is presented in Table 1.

Table 1. Annual Cost of Control per Engine
w/NO_x Adsorbers and CDPF

HP Range	**Average HP**	**Annual Control Cost ($/HP)**	**Annual Control Cost per Engine ($/yr)**
50-75	63	2	126
75-100	88	2	176
100-175	135	2	270
175-300	238	2	476
300-600	450	2	900
600-750	675	2	1,350
750-1,200	975	2	1,950
1,200-3,000	2,100	2	4,200
>3,000	5,000	2	10,000

Emission Reduction

The emission factors corresponding to the various tiers were obtained from Table A.2 of EPA's emission factors for nonroad CI engine modeling.[1] To determine the pollutant reduction per engine as a result of applying Tier 4 add-on control, EPA subtracted the Tier 4 level from the previous tier level. The resulting emission factors representing the reduction per engine for each size range are shown in Table 2.

Table 2. Emission Factors for NO_x and PM

[1]US EPA. Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling–Compression Ignition. EPA420-P-04-009. April 2004. NR-009c.

HP Range	Emission Factor (g/HP-hr)					
	NO_x			PM		
	Previous Tier	Tier 4*	Reduction	Previous Tier	Tier 4**	Reduction
50-75***	3.0	0.30	2.700	0.20	0.0184	0.1816
75-100	3.0	0.276	2.724	0.30	0.0092	0.2908
100-175	2.5	0.276	2.224	0.22	0.0092	0.2108
175-300	2.5	0.276	2.224	0.15	0.0092	0.1408
300-600	2.5	0.276	2.224	0.15	0.0092	0.1408
600-750	2.5	0.276	2.224	0.15	0.0092	0.1408
750-1,200	2.392	0.46	1.932	0.069	0.0184	0.0506
1,200-3,000	4.1	0.46	3.640	0.069	0.0184	0.0506
>3,000	4.1	0.46	3.640	0.069	0.0184	0.0506

*Tier 4 for NO_x is based on the use NO_x adsorbers.
**Tier 4 for PM is based on the use of CDPF.
***NO_x add-on control is not required for this size range. Estimates shown are for information purposes only, assuming a hypothetical 90 percent reduction of NO_x from the previous tier.

Using the emission reduction per engine shown in Table 2, the yearly emission reduction per engine for each HP range was calculated using the following equation:

$$\frac{Reduction\ \left(\frac{g}{HP\text{-}hr}\right)\ x\ Average\ HP\ \ x\ \frac{hrs}{yr}\ x\ 0.0022046\ \frac{lb}{g}}{2{,}000\ \frac{lb}{ton}}$$

where:

Reduction = The reduction of NO_x or PM per engine for each HP range, in g/HP-hr, from Table 2,
Average HP = Average engine size for each HP range, from Table 1,
hrs/yr = Average hours of operation (1,000 hrs/yr for prime engines; 37 hrs/yr for emergency engines),
0.0022046 = Conversion factor, in lb/g, and
2,000 = Conversion factor, in ton/lb.

Based on the above equation and the emission factors representing the reduction per engine in Table 2, EPA estimated the reductions per engine per year presented in Table 3.

Table 3. Estimated Reduction of NO_x and PM per Engine w/NO_x Adsorbers and CDPF

HP Range	Reduction per Engine (tpy)			
	NO_x		PM	
	Prime	Emergency	Prime	Emergency
50-75*	0.188	0.007	0.0126	0.0005
75-100	0.264	0.010	0.0282	0.0010
100-175	0.331	0.012	0.0314	0.0012
175-300	0.583	0.022	0.0369	0.0014
300-600	1.103	0.041	0.0698	0.0026
600-750	1.655	0.061	0.1048	0.0039
750-1,200	2.076	0.077	0.0544	0.0020
1,200-3,000	8.426	0.312	0.1171	0.0043
>3,000	20.062	0.742	0.2789	0.0103

*NO_x add-on control is not required for this size range. Estimates shown are for information purposes only and are based on a hypothetical 90 percent reduction of NO_x from the previous tier.

Cost per ton

Based on the annual cost of control per engine shown in Table 1 and the reduction per engine shown in Table 3, EPA estimated the cost of control per ton of pollutant removed as shown in Table 4.

Table 4. Cost of Control per Ton of Pollutant Removed w/NO_x Adsorbers and CDPF

HP Range	Cost per ton NO_x Removed ($/ton)		Cost per ton PM Removed ($/ton)		Cost per ton NO_x+PM Removed ($/ton)	
	Prime	Emergency	Prime	Emergency	Prime	Emergency
50-75*	672	18,162	4,996	135,015	630	17,017
75-100	666	18,002	6,239	168,630	602	16,266
100-175	816	22,049	8,607	232,626	745	20,140
175-300	816	22,049	12,886	348,278	767	20,736

HP Range	Cost per ton NO_x Removed ($/ton)		Cost per ton PM Removed ($/ton)		Cost per ton NO_x+PM Removed ($/ton)	
	Prime	Emergency	Prime	Emergency	Prime	Emergency
300-600	816	22,049	12,866	348,278	767	20,736
600-750	816	22,049	12,866	348,278	767	20,736
750-1,200	939	25,382	35,857	969,121	915	24,734
1,200-3,000	498	13,472	35,857	969,121	492	13,287
>3,000	498	13,472	35,857	969,121	492	13,287

*NO_x add-on control is not required for this size range. Estimates shown are for information purposes only and are based on a hypothetical 90 percent reduction of NO_x from the previous tier.

The EPA also evaluated the cost per ton of using selective catalytic reduction (SCR). The NO_x reduction using SCR is expected to be the same as NO_x adsorber, i.e., about 90 percent, so the EPA used the NO_x reduction shown in Table 3 to estimate the cost per ton with SCR. Based on information received from control technology vendors, EPA estimated SCR annual control costs of $36/HP per engine. The resulting costs per ton of NO_x removed for various stationary CI engine sizes are shown in Table 5.

Table 5. Cost of Control per Ton of NO_x Removed w/SCR

HP Range	SCR Annual Control Cost per Engine ($/yr)	NO_x Reduction per Engine		Cost per ton NO_x Removed ($/ton)	
		Prime	Emergency	Prime	Emergency
50-75	2,268	0.188	0.007	12,096	326,917
75-100	3,168	0.264	0.010	11,989	324,036
100-175	4,860	0.331	0.012	14,685	396,886
175-300	8,568	0.583	0.022	14,685	396,886
300-600	16,200	1.103	0.041	14,685	396,886
600-750	24,300	1.655	0.061	14,685	396,886
750-1,200	35,100	2.076	0.077	16,904	456,871
1,200-3,000	75,600	8.426	0.312	8,972	242,493

HP Range	SCR Annual Control Cost per Engine ($/yr)	NO_x Reduction per Engine		Cost per ton NO_x Removed ($/ton)	
		Prime	Emergency	Prime	Emergency
>3,000	180,000	20.062	0.742	8,972	242,493

Finally, EPA evaluated the cost per ton of using oxidation catalyst. The technology can reduce PM emissions up to 30 percent from stationary CI engines. Based on information obtained from the Office of Transportation and Air Quality for oxidation catalysts, EPA developed oxidation control costs following the methodology discussed in the control cost memorandum referenced earlier in this memorandum. Using that methodology, EPA estimated an average annual cost of control for oxidation catalysts of $0.30/HP per engine. Assuming oxidation catalysts will reduce PM emissions by 30 percent from stationary CI engines, EPA estimated the cost per ton of PM removed for various stationary CI engine sizes as shown in Table 6.

Table 6. Cost of Control per Ton of PM Removed w/Oxidation Catalyst

HP Range	Oxidation Catalyst Annual Control Cost per Engine ($/yr)	PM Reduction per Engine		Cost per ton PM Removed ($/ton)	
		Prime	Emergency	Prime	Emergency
50-75	19	0.004	0.0002	4,536	122,594
75-100	26	0.009	0.0003	3,024	81,729
100-175	41	0.010	0.0004	4,124	111,449
175-300	71	0.012	0.0004	6,048	163,458
300-600	135	0.022	0.0008	6,048	163,458
600-750	203	0.033	0.0012	6,048	163,458
750-1,200	293	0.022	0.0008	13,148	355,344
1,200-3,000	630	0.048	0.0018	13,148	355,344
>3,000	1,500	0.114	0.0042	13,148	355,344