

Under Review - Subject to Revision

OFFROAD Modeling Change Technical Memo

SUBJECT: Addition of Tier 4 Emission Factors to Off-road Large Compression-Ignited Engines (>25 hp)

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Summary

The statewide off-road large compression-ignited (CI) engines (>25 hp) emission inventory has not been updated since 1999. On June 29, 2004, the United States Environmental Protection Agency (U.S. EPA) set forth requirements (Tier 4 standards) for non-road diesel engines and equipment in Title 40, Code of Federal Regulations, Part 1039. Subsequently, these standards were adopted as Resolution 04-43 by the Air Resources Board on December 9, 2004. The addition of the Tier 4 standards will significantly reduce the total off-road CI engine emissions inventory. Tables 1 and 2 show a statewide oxides of nitrogen (NOx) reduction of 23 tons per day (tpd) in 2015 and 73 tpd NOx reduction in 2020.

**Table 1. Tier 4 Off-road Diesel Engines Standards
Cy 2015 Annual Average Impact (tons per day)**

Region	ROG	NOX	PM
Statewide	-1	-23	-3
South Coast	0	-6	-1
Sacramento Valley	0	-2	0
San Joaquin Valley	0	-3	-1
San Francisco	0	-5	-1
San Diego	0	-2	0

**Table 2. Tier 4 Off-road Diesel Engines Standards
Cy 2020 Annual Average Impact (tons per day)**

Region	ROG	NOX	PM
Statewide	-3	-73	-8
South Coast	-1	-21	-2
Sacramento Valley	0	-6	-1
San Joaquin Valley	0	-11	-1
San Francisco	-1	-17	-2
San Diego	0	-5	-1

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Background

Currently, the emission factors in the OFFROAD Model are based on Tier 1, 2 and 3 emission standards for CI engines greater than 25 hp. For a more detailed description of these off-road CI emission factors, please refer to Mail-Out MSC# 99-32 at: <http://www.arb.ca.gov/msei/off-road/pubs.htm> .

Manufacturers of new off-road CI engines and equipment would be subject to additional responsibilities to reduce emissions under this new Tier 4 regulation. The ARB staff report presents the regulation in greater detail, and can be found at: <http://www.arb.ca.gov/regact/offrdcie/offrdcie.htm>.

Methodology

Appendix A summarizes the phase-in schedule of the Tier 4 emissions standards which are applicable by horsepower category beginning in 2008. Appendix B shows all of the diesel emission factors used in the OFFROAD model, highlighting the Tier 4 emission standards. These emission factors were derived by applying the ratio of the Tier 4 to Tier 3 standards to the Tier 3 zero-hour emission rate.

Modeling Change

The OFFROAD Model will be modified to incorporate the Tier 4 emission factors shown in Appendix A. The emission rates will take the form of a zero-hour rate (ZHR) and a deterioration rate (DR), which is a function of equipment age. The equation used to derive the emission and deterioration rates can be found in Mail-Out MSC# 99-32 (see above for website link to document). The new Tier 4 emission factors were derived by taking the ratio-of-the-standards. In the OFFROAD Model, the emission rate for 51-120 hp is comprised of a combination of 43% of U.S. EPA's 50-75 hp standard and 57% of U.S. EPA's 76-100 hp standard. This split was derived by the U.S. EPA during the development of their NONROAD Model. For a more detailed description, please refer to the technical support documents at: <http://www.epa.gov/nonroad-diesel/2003nprm.htm#technicalsupport> . For the >750 hp category, the emission factors are based on the U.S. EPA's >750 hp 'All Other' standards.

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Appendix A

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TIER 4 DIESEL ENGINE STANDARDS AND IMPLEMENTATION SCHEDULE NMHC, NOx, and PM (g/bhp-hr)

Hp(kW)	2008	2009	2010	2011	2012	2013	2014	2015	
<11(8)	- 0.30 / 0.60*		- 0.30 / 0.45*						NMHC NOx PM
≥11 (8) <25 (19)	- 0.30								NMHC NOx PM
≥25 (19) <50 (37)	- 0.22					- 3.2 0.02			NMHC NOx PM
≥50 (37) <75 (56)	- 3.2 0.22 / 0.30**				0.02**	- 0.02			NMHC NOx PM
≥75 (56) <100 (75)					0.14 (25%) 2.5 0.01 (100%)	25% - 100%	25% - 100%	100% 0.3 100%	NMHC NOx PM
≥100 (75) <175 (130)					0.14 (25%) 2.5 0.01 (100%)	25% - 100%	25% - 100%	100% 0.3 100%	NMHC NOx PM
≥175 (130) <300 (225)				0.14 (50%) 1.5 0.01 (100%)	50% - 100%	50% - 100%	100% 0.3 100%		NMHC NOx PM
≥300 (225) <600 (450)				0.14 (50%) 1.5 0.01 (100%)	50% - 100%	50% - 100%	100% 0.3 100%		NMHC NOx PM
≥600 (450) <750 (560)				0.14 (50%) 1.5 0.01 (100%)	50% - 100%	50% - 100%	100% 0.3 100%		NMHC NOx PM
≥750 (560) Gen ≤1200 HP				- 2.6 0.075	- - -	- - -	- - -	0.14 0.5 0.02	NMHC NOx PM
≥750 (560) Gen >1200 HP				- 0.5 0.075	- - -	- - -	- - -	0.14 - 0.02	NMHC NOx PM
≥750 (560) All Other				- 2.6 0.075	- - -	- - -	- - -	0.14 - 0.03	NMHC NOx PM

* Standards for hand-start, air cooled, direct injection engines < 11 hp will not be required until 2010 at which time a 0.45 g/hp-hr PM provision would apply to a negligible percentage of that category.

** Manufacturers meeting 0.22 PM in 2008 don't have to meet 0.02 PM until 2013, otherwise they must meet 0.02 PM one year earlier in 2012.

Appendix B

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OFFROAD Model Diesel Emission Factors (g/hp-hr) Highlighting the Tier 4 Standards

		(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)
HP	Year	HC	HC det	CO	CO det	NOX	NOX det	PM	PM det
26 - 50	<= 1987	1.84	2.35E-04	5	5.13E-04	7	1.05E-04	0.76	5.89E-05
26 - 50	1988 - 1998	1.8	2.30E-04	5	5.13E-04	6.9	1.04E-04	0.76	5.89E-05
26 - 50	1999 - 2003	1.45	1.85E-04	4.1	4.20E-04	5.55	1.03E-04	0.6	4.65E-05
26 - 50	2004	0.64	9.80E-05	3.27	3.34E-04	5.1	9.33E-05	0.43	3.36E-05
26 - 50	2005	0.37	6.90E-05	3	3.05E-04	4.95	9.67E-05	0.38	2.93E-05
26 - 50	2006 - 2007	0.24	5.45E-05	2.86	2.90E-04	4.88	9.83E-05	0.35	2.72E-05
26 - 50	2008 - 2012	0.1	4.00E-05	2.72	2.76E-04	4.8	1.00E-04	0.16	1.22E-05
26 - 50	2013 - 2020	0.1	4.00E-05	2.72	2.76E-04	2.9	6.04E-05	0.01	1.11E-06
51 - 120	<= 1987	1.44	6.66E-05	4.8	1.27E-04	13	3.01E-04	0.84	6.11E-05
51 - 120	1988 - 1997	0.99	4.58E-05	3.49	9.23E-05	8.75	2.02E-04	0.69	5.02E-05
51 - 120	1998 - 2003	0.99	4.58E-05	3.49	9.23E-05	6.9	1.60E-04	0.69	5.02E-05
51 - 120	2004	0.46	3.33E-05	3.23	8.55E-05	5.64	1.03E-04	0.39	2.85E-05
51 - 120	2005	0.28	2.92E-05	3.14	8.33E-05	5.22	8.40E-05	0.29	2.12E-05
51 - 120	2006 - 2007	0.19	2.71E-05	3.09	8.21E-05	5.01	7.45E-05	0.24	1.76E-05
51 - 120	2008 - 2011	0.1	2.50E-05	3.05	8.10E-05	2.89	3.80E-05	0.2	1.45E-05
51 - 120	2012	0.09	2.31E-05	3.05	8.10E-05	2.53	3.33E-05	0.07	4.96E-06
51 - 120	2013 - 2014	0.09	2.31E-05	3.05	8.10E-05	2.53	3.33E-05	0.01	9.33E-07
51 - 120	2015 - 2020	0.07	1.74E-05	3.05	8.10E-05	1.4	1.84E-05	0.01	9.33E-07
121 - 175	<= 1969	1.32	6.11E-05	4.4	1.16E-04	14	3.24E-04	0.77	5.60E-05
121 - 175	1970 - 1971	1.1	5.09E-05	4.4	1.16E-04	13	3.01E-04	0.66	4.80E-05
121 - 175	1972 - 1979	1	4.63E-05	4.4	1.16E-04	12	2.78E-04	0.55	4.00E-05
121 - 175	1980 - 1984	0.94	4.35E-05	4.3	1.14E-04	11	2.54E-04	0.55	4.00E-05
121 - 175	1985 - 1987	0.88	4.07E-05	4.2	1.11E-04	11	2.54E-04	0.55	4.00E-05
121 - 175	1988 - 1996	0.68	3.15E-05	2.7	7.14E-05	8.17	1.89E-04	0.38	2.76E-05
121 - 175	1997 - 2002	0.68	3.15E-05	2.7	7.14E-05	6.9	1.60E-04	0.38	2.76E-05
121 - 175	2003	0.33	2.79E-05	2.7	7.14E-05	5.26	9.64E-05	0.24	1.70E-05
121 - 175	2004	0.22	2.63E-05	2.7	7.14E-05	4.72	7.52E-05	0.19	1.35E-05
121 - 175	2005 - 2006	0.16	2.57E-05	2.7	7.14E-05	4.44	6.46E-05	0.16	1.18E-05
121 - 175	2007 - 2011	0.1	2.50E-05	2.7	7.14E-05	2.45	3.20E-05	0.14	1.00E-05
121 - 175	2012 - 2014	0.09	2.17E-05	2.7	7.14E-05	2.27	2.96E-05	0.01	4.67E-07
121 - 175	2015 - 2020	0.05	1.17E-05	2.7	7.14E-05	0.27	3.56E-06	0.01	4.67E-07
176 - 250	<= 1969	1.32	6.11E-05	4.4	1.16E-04	14	3.24E-04	0.77	5.60E-05
176 - 250	1970 - 1971	1.1	5.09E-05	4.4	1.16E-04	13	3.01E-04	0.66	4.80E-05
176 - 250	1972 - 1979	1	4.63E-05	4.4	1.16E-04	12	2.78E-04	0.55	4.00E-05
176 - 250	1980 - 1984	0.94	4.35E-05	4.3	1.14E-04	11	2.54E-04	0.55	4.00E-05
176 - 250	1985 - 1987	0.88	4.07E-05	4.2	1.11E-04	11	2.54E-04	0.55	4.00E-05
176 - 250	1988 - 1995	0.68	3.15E-05	2.7	7.14E-05	8.17	1.89E-04	0.38	2.76E-05
176 - 250	1996 - 2002	0.32	1.48E-05	0.92	2.43E-05	6.25	1.45E-04	0.15	7.96E-06
176 - 250	2003	0.19	2.09E-05	0.92	2.43E-05	5	9.05E-05	0.12	6.51E-06
176 - 250	2004	0.14	2.30E-05	0.92	2.43E-05	4.58	7.23E-05	0.11	6.03E-06
176 - 250	2005 - 2006	0.12	2.40E-05	0.92	2.43E-05	4.38	6.33E-05	0.11	5.79E-06
176 - 250	2007 - 2010	0.1	2.50E-05	0.92	2.43E-05	2.45	3.18E-05	0.11	5.59E-06
176 - 250	2011 - 2013	0.07	1.83E-05	0.92	2.43E-05	1.36	1.77E-05	0.01	4.55E-07
176 - 250	2014 - 2020	0.05	1.17E-05	0.92	2.43E-05	0.27	3.56E-06	0.01	4.55E-07

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(Continued)

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		(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)	(g/hp-hr)	(g/hp-hr ²)
HP	Year	HC	HC det	CO	CO det	NOX	NOX det	PM	PM det
251 - 500	<= 1969	1.26	4.39E-05	4.2	8.32E-04	14	2.33E-04	0.74	3.93E-05
251 - 500	1970 - 1971	1.05	3.66E-05	4.2	8.32E-04	13	2.16E-04	0.63	3.34E-05
251 - 500	1972 - 1979	0.95	3.31E-05	4.2	8.32E-04	12	2.00E-04	0.53	2.81E-05
251 - 500	1980 - 1984	0.9	3.14E-05	4.2	8.32E-04	11	1.83E-04	0.53	2.81E-05
251 - 500	1985 - 1987	0.84	2.93E-05	4.1	8.12E-04	11	1.83E-04	0.53	2.81E-05
251 - 500	1988 - 1995	0.68	2.37E-05	2.7	5.35E-05	8.17	1.36E-04	0.38	2.02E-05
251 - 500	1996 - 2000	0.32	1.12E-05	0.92	1.82E-05	6.25	1.04E-04	0.15	7.96E-06
251 - 500	2001	0.19	1.95E-05	0.92	1.82E-05	4.95	7.34E-05	0.12	6.51E-06
251 - 500	2002	0.14	2.22E-05	0.92	1.82E-05	4.51	6.32E-05	0.11	6.03E-06
251 - 500	2003 - 2004	0.12	2.36E-05	0.92	1.82E-05	4.29	5.81E-05	0.11	5.79E-06
251 - 500	2005 - 2010	0.1	2.50E-05	0.92	1.82E-05	2.45	3.18E-05	0.11	5.55E-06
251 - 500	2011 - 2013	0.07	1.83E-05	0.92	1.82E-05	1.36	1.77E-05	0.01	4.55E-07
251 - 500	2014 - 2020	0.05	1.17E-05	0.92	1.82E-05	0.27	3.56E-06	0.01	4.55E-07
501 - 750	<= 1969	1.26	4.39E-05	4.2	8.32E-04	14	2.33E-04	0.74	3.93E-05
501 - 750	1970 - 1971	1.05	3.66E-05	4.2	8.32E-04	13	2.16E-04	0.63	3.34E-05
501 - 750	1972 - 1979	0.95	3.31E-05	4.2	8.32E-04	12	2.00E-04	0.53	2.81E-05
501 - 750	1980 - 1984	0.9	3.14E-05	4.2	8.32E-04	11	1.83E-04	0.53	2.81E-05
501 - 750	1985 - 1987	0.84	2.93E-05	4.1	8.12E-04	11	1.83E-04	0.53	2.81E-05
501 - 750	1988 - 1995	0.68	2.37E-05	2.7	5.35E-05	8.17	1.36E-04	0.38	2.02E-05
501 - 750	1996 - 2001	0.32	1.12E-05	0.92	1.82E-05	6.25	1.04E-04	0.15	7.96E-06
501 - 750	2002	0.19	1.95E-05	0.92	1.82E-05	4.95	7.34E-05	0.12	6.51E-06
501 - 750	2003	0.14	2.22E-05	0.92	1.82E-05	4.51	6.32E-05	0.11	6.03E-06
501 - 750	2004 - 2005	0.12	2.36E-05	0.92	1.82E-05	4.29	5.81E-05	0.11	5.79E-06
501 - 750	2006 - 2010	0.1	2.50E-05	0.92	1.82E-05	2.45	3.18E-05	0.11	5.55E-06
501 - 750	2011 - 2013	0.07	1.83E-05	0.92	1.82E-05	1.36	1.77E-05	0.01	4.55E-07
501 - 750	2014 - 2020	0.05	1.17E-05	0.92	1.82E-05	0.27	3.56E-06	0.01	4.55E-07
751 - 9999	<= 1969	1.26	4.39E-05	4.2	8.32E-04	14	2.33E-04	0.74	3.93E-05
751 - 9999	1970 - 1971	1.05	3.66E-05	4.2	8.32E-04	13	2.16E-04	0.63	3.34E-05
751 - 9999	1972 - 1979	0.95	3.31E-05	4.2	8.32E-04	12	2.00E-04	0.53	2.81E-05
751 - 9999	1980 - 1984	0.9	3.14E-05	4.2	8.32E-04	11	1.83E-04	0.53	2.81E-05
751 - 9999	1985 - 1987	0.84	2.93E-05	4.1	8.12E-04	11	1.83E-04	0.53	2.81E-05
751 - 9999	1988 - 1999	0.68	1.12E-05	2.7	5.35E-05	8.17	1.36E-04	0.38	2.02E-06
751 - 9999	2000 - 2005	0.32	1.12E-05	0.92	1.82E-05	6.25	1.04E-04	0.15	7.96E-06
751 - 9999	2006	0.19	1.95E-05	0.92	1.82E-05	4.95	7.34E-05	0.12	6.51E-06
751 - 9999	2007	0.14	2.22E-05	0.92	1.82E-05	4.51	6.32E-05	0.11	6.03E-06
751 - 9999	2008 - 2009	0.12	2.36E-05	0.92	1.82E-05	4.29	5.81E-05	0.11	5.79E-06
751 - 9999	2010	0.1	2.50E-05	0.92	1.82E-05	4.08	5.30E-05	0.11	5.55E-06
751 - 9999	2011 - 2014	0.1	2.50E-05	0.92	1.82E-05	2.36	3.06E-05	0.06	2.78E-06
751 - 9999	2015 - 2020	0.05	1.17E-05	0.92	1.82E-05	2.36	3.06E-05	0.02	1.11E-06