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Mobile Source Observation Data (MSOD) Database Update

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Mobile Source Observation Data (MSOD) Database Update

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by
Eastern Research Group, Inc.
EPA Contract No. 68-C-00-112
Work Assignment No. 2-06

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

Mobile Source Observation Data (MSOD) Database Update

INTERIM REPORT
REVISION 2

Prepared for:

U.S. Environmental Protection Agency

October 31, 2002

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Work Assignment No.: 2-06

Mobile Source Observation Data (MSOD) Database Update

INTERIM REPORT
REVISION 2

EPA Contract No. 68-C-00-112
Work Assignment No. 2-06

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October 31, 2002

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1.0 Introduction

The United States Environmental Protection Agency (EPA) is in the process of creating a new mobile source emissions modeling system entitled the Multi-Scale Motor Vehicle and Equipment Emission System (MOVES). This new model will generate emissions factors in units of grams per second. This is a marked difference from previous models, such as MOBILE6, which were based on factors in grams per mile. Much of the new factor development will be based on the vehicle testing information contained within EPA's Mobile Source Observation Database (MSOD).

The goal of this project is to augment the data currently in the MSOD with data collected by other entities such as research groups and industry organizations. Towards this end, ERG staff have contacted numerous vehicle-testing organizations and investigated the availability of vehicle testing data. This investigation focused on tests that recorded second by second emissions results with emphasis placed on greenhouse gas exhaust emissions, i.e CO_2, CH_4, and N_2O. Appendix A contains a description of the type of vehicle test information that is targeted for this project.

Each of the different data sources were questioned by EPA or ERG staff to determine what type of vehicle test data they have that could be included in the EPA MSOD and made available for public access. The available data can be generally grouped as stemming from either an inspection and maintenance (I/M) program, or a special study. This report presents a review of the different datasets that are of interest and are being considered for inclusion into the MSOD. In some instances only a sample of the data was available for review at the time that this report was written and the statistics presented should be taken as only an example of the type of information that is available.

Also included in this report is a brief discussion of other datasets that have been determined to be available outside of the time frame of this project. These datasets will be discussed briefly and highlighted for possible examination in the future.

2.0 Inspection and Maintenance Programs

2.1 Overview

Test data from three inspection and maintenance (I/M) programs were highlighted for collection and inclusion into the MSOD. The selected programs were the Arizona Car Care program, British Columbia AirCare program, and the Colorado Air Care program. All three programs use centralized testing facilities operated by a primary contractor with tests administered by trained technicians. A summary of the program details appears below in Table 2-1.

Table 2-1: I/M Program Details

State	Cities	Network Type	Test Type	Evap Tests	Frequency	Vehicle Types	Model Years	Start Date	OBD testing
Arizona	Phoenix	Test Only	81-95: IM 147 <81: Loaded Idle 96+: OBD	pressure Gas Cap	Annual 1967-80 Biennial 1981+	LDGVs, LDGTs, HDBVs, MC	1967+ <4 exempt	Jan-95	pass/fail: 1/02
Colorado	Denver and Boulder	Test Only	82+: IM240 <82: 2 speed Idle	Gas Cap	82+: Biennial <82 Annual	LDGVs, LDGTs, HDGVs	All except <4 exempt	Jan-95	MIL fail only
British Columbia		Test Only	<=1991 ASM >1991 IM240	pressure Gas Cap	1992+ : Biennial <1992 Annual	LDGV, LDGT, HDGT, DIiesel	All except <2 exempt	Sep-92	

Different amounts of data were available from each of the programs as detailed in Table 2-2 below. At the time this report was written only a one month sample set of data was available from the Colorado I/M program. The table below lists both the sample set and the estimates for the full Colorado data set.

Table 2-2: Coverage of Datasets

Program	Start Date	End Date	Number of Tests
Arizona	January 1, 2002	June 30, 2002	317,192
Colorado Sample	January 1, 2002	January 31, 2002	128,682
Colorado Full Set Estimates	January 1, 1999	September 1, 2002	3,000,000
British Columbia	January 1, 2001	June 3, 2002	1,414,356

The vehicles in each dataset have been categorized by model year into groupings of similar technologies or standards for summary purposes. Since there is not a strict correlation between model year and technology used, this grouping should be viewed as a generalization only. The model year ranges used are shown in Table 2-3.

Table 2-3: Model Year Groupings

Model Year	Technology Grouping
Pre-1975	Non-Catalyst
1975-1980	Oxidation Catalyst
1981-1985	3-Way Catalyst
1986-1993	Tier 0
1994-2000	Tier 1
2001-2003	NLEV
2004 and newer	Tier 2

In each of the following sub sections there will be a brief discussion of the I/M program followed by summary statistical data for each program. In the following three tables that summary data is shown for all three I/M programs combined.

Table 2-4: Number of Tests for Each Vehicle Type for All Three I/M Programs

Vehicle Type	Model Year Group							Grand Total
	Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
LDV	20018	33843	127936	632126	311815	3403		1129141
LDT	6134	6193	40554	285659	230207	2704		571451
HDT	1408	16925	15153	24912	13794	349		72541
DIES	75	1101	5825	8937	6718	6		22662
Missing	1074	2539	7737	38000	13478	13	1526	64367
Grand Total	28709	60601	197205	989634	576012	6475	1526	1860162

Table 2-5: Number of Tests for Mileage Groupings for All Three I/M Programs

Mileage	Vehicle Type	Model Year Group							Grand Total
		Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
Mileage < 50K	LDV	5226	5012	9503	28657	97016	3350		148764
	LDT	1690	1628	4087	11799	55850	2573		77627
	HDT	300	2536	1698	1600	3521	338		9993
	DIES	11	74	123	195	1320	5		1728
	Missing	242	325	418	7220	5281	10		13496
Mileage < 50K Total		7469	9575	15829	49471	162988	6276		251608
Mileage > 50K	LDV	14778	28804	118110	602024	214096	53		977865
	LDT	4433	4543	36231	273242	173757	131		492337
	HDT	1108	14389	13455	23312	10273	11		62548
	DIES	64	1027	5702	8742	5398	1		20934
	Missing	742	2134	7124	30089	7571	2		47662
Mileage > 50K Total		21125	50897	180622	937409	411095	198		1601346
Missing	LDV	14	27	323	1445	703			2512
	LDT	11	22	236	618	600			1487
	Missing	90	80	195	691	626	1	1526	3209
Missing Total		115	129	754	2754	1929	1	1526	7208
Grand Total		28709	60601	197205	989634	576012	6475	1526	1860162

Table 2-6: Number of Tests for Each Fuel Type Used from All Three I/M Programs

Fuel	Model Year Group							Grand Total
	Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
Alcohol	4		1	2	1			8
Butane			2	16	12	2		32
Compressed Natural Gas			1	83	772	148		1004
Diesel	83	1148	6128	9213	7439	6		24017
Diesel-Butane				1	7			8
Diesel-Natural Gas			1		1			2
Diesel-Propane	3				3			6
E85					1			1
Gasoline	27687	54733	181772	950137	560465	6141		1780935
Gasoline-Alcohol	3	5	8	36	19			71
Gasoline-Electric	2	1	5	11	19	2		40
Gasoline-Natura lGas	51	252	549	2096	540			3488
Gasoline-Propane	58	269	308	1881	336			2852
LNG		1		4	2			7
LPG	1	7	7	18	15			48
M85				1				1
Multi-fuels				12	2			14
Natura lGas	8	74	106	178	379	1		746
Other				3	12			15
Propane	358	2712	3999	10224	2198	164		19655
Propane-Natural Gas		1		8	2			11
Missing	451	1398	4318	15710	3787	11	1526	27201
Grand Total	28709	60601	197205	989634	576012	6475	1526	1860162

2.2 Arizona Car Care

Arizona has been conducting an enhanced vehicle-testing program in Phoenix since 1995. As part of this program most light duty gasoline vehicles with model years 1981 through 1995 undergo an IM 147 test on a biennial basis. Arizona has provided the results of all IM 147 tests performed from January through June 2002 for inclusion into the EPA MSOD [1, 2, 3].

Summary statistics for the Arizona data appear in the tables below.

Table 2–7: Number of Tests for Each Vehicle Type

Model Year Group	Vehicle Type			Grand Total
	LDT1	LDT2	LDV	
1. Non-catalyst	12	10	28	50
2. Oxidation catalyst	12	32	54	98
3. 3-way catalyst	10355	4900	21095	36350
4. Tier 0	49144	14122	119113	182379
5. Tier 1	29875	13292	54466	97633
6. NLEV	30	573	79	682
Grand Total	89428	32929	194835	317192

Table 2–8: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type			Grand Total
		LDV	LDT1	LDT2	
Mileage < 50K	1. Non-catalyst	2	3	1	6
	2. Oxidation catalyst	2		4	6
	3. 3-way catalyst	2834	1189	727	4750
	4. Tier 0	11015	4037	1501	16553
	5. Tier 1	6716	2242	1688	10646
	6. NLEV	60	23	488	571
Mileage < 50K Total		20629	7494	4409	32532
Mileage > 50K	1. Non-catalyst	12	3	4	19
	2. Oxidation catalyst	25	6	12	43
	3. 3-way catalyst	17938	9013	4090	31041
	4. Tier 0	106653	44652	12458	163763
	5. Tier 1	47047	27214	11423	85684
	6. NLEV	19	7	85	111
Mileage > 50K Total		171694	80895	28072	280661
Missing	1. Non-catalyst	14	6	5	25
	2. Oxidation catalyst	27	6	16	49
	3. 3-way catalyst	323	153	83	559
	4. Tier 0	1445	455	163	2063
	5. Tier 1	703	419	181	1303
Missing Total		2512	1039	448	3999
Grand Total		194835	89428	32929	317192

Table 2–9: Number of Tests for Each Fuel Type and Vehicle Type

Fuel	Model Year Group	Vehicle Type			Grand Total
		LDV	LDT1	LDT2	
Butane	3. 3-way catalyst	1			1
	4. Tier 0		7	1	8
	5. Tier 1	1			1
	6. NLEV			2	2
Butane Total		2	7	3	12
Compressed Natural Gas	3. 3-way catalyst	1			1
	4. Tier 0	24	36	7	67
	5. Tier 1	214	73	465	752
	6. NLEV	17	6	123	146
Compressed Natural Gas Total		256	115	595	966
Gasoline	1. Non-catalyst	14	6	5	25
	2. Oxidation catalyst	27	6	14	47
	3. 3-way catalyst	20769	10200	4807	35776
	4. Tier 0	117625	48618	13929	180172
	5. Tier 1	53225	29362	12450	95037
	6. NLEV	52	19	299	370
Gasoline Total		191712	88211	31504	311427
Other	4. Tier 0	2		1	3
	5. Tier 1	5	5	2	12
Other Total		7	5	3	15
Propane	2. Oxidation catalyst			2	2
	3. 3-way catalyst	1	2	10	13
	4. Tier 0	17	28	21	66
	5. Tier 1	318	16	194	528
	6. NLEV	10	5	149	164
Propane Total		346	51	376	773
Missing	1. Non-catalyst	14	6	5	25
	2. Oxidation catalyst	27	6	16	49
	3. 3-way catalyst	323	153	83	559
	4. Tier 0	1445	455	163	2063
	5. Tier 1	703	419	181	1303
Missing Total		2512	1039	448	3999
Grand Total		194835	89428	32929	317192

Table 2–10: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	317,192	0	1967	2003	1991	3.84
Cylinders	0	317,192	.	.	.	.
Displacement (L)	0	317,192	.	.	.	.
Ambient Humidity (%)	317,192	0	0.00	99.92	25.43	13.82
Ambient Pressure	317,192	0	27.08	30.76	28.65	0.23
Ambient Temperature (F)	317,192	0	1.85	121.97	75.58	14.53
Horsepower	317,192	0	7.30	33.90	14.57	3.41
Curb Weight (lbs)	0	317,192	.	.	.	.
Inertia Weight (lbs)	317,192	0	1750	6000	3510.20	662.03
Odometer (in thousands)	313,193	3,999	0	255	110.03	50.05

Documentation rating: A. Fully Documented
Information on the Arizona Car Care program can be found on their web site at: http://www.ev.state.az.us/environ/air/vei/index.html (last verified October 24, 2002). Multiple documents exist for the Arizona's Car Care program detailing the entire I/M program. The program has been audited both internally and externally and the reports are readily available. Some of the reports of interest are:

1. *Profiling and Prediction of Individual Arizona Vehicle IM147 Pass/Fail Results*, prepared by Eastern Research Group (ERG) for Air Quality Division, Arizona Department of Environmental Quality, June 27, 2002.

2. *Analysis of Arizona I/M Program Repair Data*, prepared by Eastern Research Group (ERG) for Air Quality Division, Arizona Department of Environmental Quality, June 28, 2002.

3. *Baseline Analysis of Enhanced I/M Compliance*, prepared by Eastern Research Group (ERG) for Air Quality Division, Arizona Department of Environmental Quality, June 28, 2002.

Completeness rating: C. Missing Data
The Car Care program did not record all of the data fields listed as being of interest in Appendix A. The fuel parameters were not included and all tests were conducted with the fuel that was in the vehicle when it arrived at the testing facility (tank fuel).

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2.3 British Columbia AirCare

A vehicle inspection and maintenance program entitled AirCare was started in British Columbia, Canada, in 1992. This program originally used centralized testing facilities to perform ASM 2525/idle test procedures. In 2000 the program was reviewed and modified into AirCare II. In the new program IM240 tests were used for vehicle model years over 1991. Data from the AirCare from January 2001 through June 2002 program has been made available for inclusion into EPA's MSOD [1, 2, 3].

Summary statistics for the AirCare data appear in the tables below.

Table 2–11: Number of Tests for Each Vehicle Type

Model Year Group	Vehicle Type					Grand Total
	LDGV	LDGT	HDGT	DIES	Missing	
1. Non-catalyst	18462	4818	1252	75	1074	25681
2. Oxidation catalyst	31159	3377	16200	1101	2539	54376
3. 3-way catalyst	101581	21669	14233	5825	7737	151045
4. Tier 0	484229	207237	22015	8937	38000	760418
5. Tier 1	227074	164508	9343	6718	13478	421121
6. NLEV	43	123	4	6	13	189
0. Missing					1526	1526
Grand Total	862548	401732	63047	22662	64367	1414356

Table 2–12: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type					Grand Total
		LDGV	LDGT	HDGT	DIES	Missing	
Mileage < 50K	1. Non-catalyst	4512	1130	224	11	242	6119
	2. Oxidation catalyst	4048	454	2198	74	325	7099
	3. 3-way catalyst	5430	1131	1278	123	418	8380
	4. Tier 0	14072	3833	840	195	7220	26160
	5. Tier 1	79843	44853	2216	1320	5281	133513
	6. NLEV	40	120	4	5	10	179
Mileage < 50K Total		107945	51521	6760	1728	13496	181450
Mileage > 50K	1. Non-catalyst	13950	3688	1028	64	742	19472
	2. Oxidation catalyst	27111	2923	14002	1027	2134	47197
	3. 3-way catalyst	96151	20538	12955	5702	7124	142470
	4. Tier 0	470157	203404	21175	8742	30089	733567
	5. Tier 1	147231	119655	7127	5398	7571	286982
	6. NLEV	3	3		1	2	9
Mileage > 50K Total		754603	350211	56287	20934	47662	1229697
Missing	1. Non-catalyst					90	90
	2. Oxidation catalyst					80	80
	3. 3-way catalyst					195	195
	4. Tier 0					691	691
	5. Tier 1					626	626
	6. NLEV					1	1
	Missing					1526	1526
Missing Total						3209	3209
Grand Total		862548	401732	63047	22662	64367	1414356

Table 2–13: Number of Tests for Each Fuel Type and Vehicle Type

Fuel	Model Year Group	Vehicle Type					Grand Total
		LDGV	LDGT	HDGT	DIES	Missing	
Alcohol	1. Non-catalyst		4				4
	3. 3-way catalyst	1					1
	4. Tier 0					2	2
	5. Tier 1	1					1
Alcohol Total		2	4			2	8
Butane	3. 3-way catalyst	1					1
	4. Tier 0	2	2			4	8
	5. Tier 1	7	4				11
Butane Total		10	6			4	20
Diesel	1. Non-catalyst				75	8	83
	2. Oxidation catalyst				1101	47	1148
	3. 3-way catalyst				5825	303	6128
	4. Tier 0				8937	276	9213
	5. Tier 1				6718	721	7439
	6. NLEV				6		6
Diesel Total					22662	1355	24017
Diesel-Butane	4. Tier 0		1				1
	5. Tier 1	3	2			2	7
Diesel-Butane Total		3	3			2	8
Diesel-Natural Gas	3. 3-way catalyst	1					1
	5. Tier 1		1				1
Diesel-Natural Gas Total		1	1				2
Diesel-Propane	1. Non-catalyst		2	1			3
	5. Tier 1		1			2	3
Diesel-Propane Total			3	1		2	6
Gasoline	1. Non-catalyst	18357	4604	1092		639	24692
	2. Oxidation catalyst	30659	3139	13737		1040	48575
	3. 3-way catalyst	100896	20665	11106		3541	136208
	4. Tier 0	482607	200259	16653		23741	723260
	5. Tier 1	226489	162877	8681		10463	408510
	6. NLEV	41	122	4		12	179
Gasoline Total		859049	391666	51273		39436	1341424
Gasoline-Alcohol	1. Non-catalyst	3					3
	2. Oxidation catalyst	5					5
	3. 3-way catalyst	7	1				8
	4. Tier 0	21	11	2		2	36
	5. Tier 1	9	8			2	19
Gasoline-Alcohol Total		45	20	2		4	71

Table continued on next page.

Table 2–13: Number of Tests for Each Fuel Type and Vehicle Type (Continued)

Fuel	Model Year Group	Vehicle Type	Grand Total

		LDGV	LDGT	HDGT	DIES	Missing	
Gasoline-Electric	1. Non-catalyst	1		1			2
	2. Oxidation catalyst			1			1
	3. 3-way catalyst	5					5
	4. Tier 0	5	3	2		1	11
	5. Tier 1	17	2				19
	6. NLEV	1	1				2
Gasoline-Electric Total		29	6	4		1	40
Gasoline-Natural Gas	1. Non-catalyst	24	11	12		4	51
	2. Oxidation catalyst	80	7	150		15	252
	3. 3-way catalyst	142	121	262		24	549
	4. Tier 0	379	1196	465		56	2096
	5. Tier 1	124	307	95		14	540
Gasoline-Natural Gas Total		749	1642	984		113	3488
Gasoline-Propane	1. Non-catalyst	8	25	24		1	58
	2. Oxidation catalyst	28	13	204		24	269
	3. 3-way catalyst	49	64	178		17	308
	4. Tier 0	77	949	764		91	1881
	5. Tier 1	13	231	71		21	336
Gasoline-Propane Total		175	1282	1241		154	2852
Multi-fuels	4. Tier 0	9				3	12
	5. Tier 1	2					2
Multi-fuels Total		11				3	14
Natural Gas	1. Non-catalyst	5		3			8
	2. Oxidation catalyst	18	5	48		3	74
	3. 3-way catalyst	23	25	52		6	106
	4. Tier 0	52	57	58		11	178
	5. Tier 1	177	115	79		8	379
	6. NLEV	1					1
Natural Gas Total		276	202	240		28	746
Propane	1. Non-catalyst	64	172	119		3	358
	2. Oxidation catalyst	369	213	2059		69	2710
	3. 3-way catalyst	456	793	2635		102	3986
	4. Tier 0	1077	4757	4066		258	10158
	5. Tier 1	232	958	417		63	1670
Propane Total		2198	6893	9296		495	18882

Table continued on next page.

Table 2–13: Number of Tests for Each Fuel Type and Vehicle Type (Continued)

Fuel	Model Year Group	Vehicle Type					Grand Total
		LDGV	LDGT	HDGT	DIES	Missing	
Propane-Natural Gas	2. Oxidation catalyst			1			1
	4. Tier 0		2	5		1	8
	5. Tier 1		2				2
Propane-Natural Gas Total			4	6		1	11
Missing	1. Non-catalyst					419	419
	2. Oxidation catalyst					1341	1341
	3. 3-way catalyst					3744	3744
	4. Tier 0					13554	13554
	5. Tier 1					2182	2182
	6. NLEV					1	1
	0. Missing					1526	1526
Missing Total						22767	22767
Grand Total		862548	401732	63047	22662	64367	1414356

Table 2–14: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	1,412,830	1,526	1901	2002	1990	6.18
Cylinders	1,391,475	22,881	1	12	5.37	1.52
Displacement (L)	1,411,148	3,208	0.10	91.20	3.03	1.46
Ambient Humidity (%)	1,288,987	125,369	11.70	97.20	60.96	13.89
Ambient Pressure	1,313,681	100,675	18.66	34.49	29.98	0.35
Ambient Temperature (C)	526,522	887,834	-3.10	34.60	13.55	5.39
Horsepower	1,391,588	22,768	1.20	34.70	14.05	3.56
Curb Weight (lbs)	1,411,146	3,210	1	24860	1398.03	386.48
Inertia Weight (lbs)	1,391,589	22,767	1000	8000	3395.31	725.79
Odometer (in thousands)	1,411,147	3,209	-1	999	145.12	85.18

Documentation rating: A. Fully Documented
Multiple documents exist for the AirCare project detailing the entire project. The program has been audited both internally and externally and the reports are readily available. Supporting documentation can be downloaded at their web site http://www.aircare.ca (last verified October 24, 2002). Some of the reports of interest are as follows:

1. S.J. Stewart, D.J. Gourley, and J. Wong, *AirCare® Results and Observations Relating to the First Eight Years of Operation (1992-2000).* Copies available at http://www.aircare.ca.

2. *Review of the British Columbia AirCare Program.* Prepared by Rob Klausmeier, De La Torre Klausmeier Consulting, Inc. for the Ministry of Environment, Lands and Parks, Air Resources Branch. September 15, 2000.

3. *Review of Air Quality and Motor Vehicle Technology Issues Pertaining to the Design of AirCare II.* Prepare by Sierra Research, Inc. for the Greater Vancouver Regional District. July 1998.

Completeness rating: C. Missing Data
The AirCare program did not record all of the data fields listed as being of interest in Appendix A. The fuel parameters were not included and all tests were conducted on whatever fuel was in the vehicle when it arrived at the testing facility (tank fuel).
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2.4 Colorado Air Care

Colorado's inspection and maintenance program, titled Air Care, was started in January of 1995. All 1982 and newer vehicles in Denver and surrounding effected areas are required to have an I/M240 emissions test every two years at one of the 15 Air Care testing stations. The test facilities are operated by Envirotest Systems Corp., a subsidiary of Environmental Systems Products, Inc. (ESP). Vehicles older then 1982 are only required to pass an idle emissions test annually and can be taken to any Envirotest Air Care center or to any licensed independent testing center [1].

At the time this report was written only a one-month sample set of data was available from the Colorado I/M program for tests run in January of 2002. The full dataset is expected from Colorado in early November 2002.

The summary tables below show the results of analysis from the one month sample.

Table 2–15: Number of Tests for Each Vehicle Type

Model Year Group	Vehicle Type					Grand Total
	LDGV	LDGT1	LDGT2	HDGT1	HDGT2	
1. Non-catalyst	1528	648	646	62	94	2978
2. Oxidation catalyst	2630	1177	1595	244	481	6127
3. 3-way catalyst	5260	2865	765	766	154	9810
4. Tier 0	28784	10078	5078	2260	637	46837
5. Tier 1	30275	11848	10684	3254	1197	57258
6. NLEV	3281	768	1210	219	126	5604
Grand Total	71758	27384	19978	6805	2689	128614

Table 2–16: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type					Grand Total
		LDGV	LDGT1	LDGT2	HDGT1	HDGT2	
Mileage < 50K	1. Non-catalyst	712	279	277	37	39	1344
	2. Oxidation catalyst	962	527	643	107	231	2470
	3. 3-way catalyst	1239	790	250	342	78	2699
	4. Tier 0	3570	1465	963	606	154	6758
	5. Tier 1	10457	3473	3594	877	428	18829
	6. NLEV	3250	756	1186	213	121	5526
Mileage < 50K Total		20190	7290	6913	2182	1051	37626
Mileage > 50K	1. Non-catalyst	816	369	369	25	55	1634
	2. Oxidation catalyst	1668	650	952	137	250	3657
	3. 3-way catalyst	4021	2075	515	424	76	7111
	4. Tier 0	25214	8613	4115	1654	483	40079
	5. Tier 1	19818	8375	7090	2377	769	38429
	6. NLEV	31	12	24	6	5	78
Mileage > 50K Total		51568	20094	13065	4623	1638	90988
Grand Total		71758	27384	19978	6805	2689	128614

Table 2–17: Number of Tests for Each Fuel Type and Vehicle Type

Fuel	Model Year Group	Vehicle Type					Grand Total
		LDGV	LDGT1	LDGT2	HDGT1	HDGT2	
Compressed Natural Gas	4. Tier 0	2	3	5	6		16
	5. Tier 1	5	1	9	3	2	20
	6. NLEV	1		1			2
CNG Total		8	4	15	9	2	38
E85	5. Tier 1		1				1
E85Total			1				1
Gasoline	1. Non-catalyst	1522	647	645	62	94	2970
	2. Oxidation catalyst	2625	1173	1592	243	478	6111
	3. 3-way catalyst	5245	2863	765	762	153	9788
	4. Tier 0	28686	10073	5059	2252	635	46705
	5. Tier 1	29993	11844	10644	3249	1188	56918
	6. NLEV	3271	768	1208	219	126	5592
Gasoline Total		71342	27368	19913	6787	2674	128084
Liquefied Natural Gas	2. Oxidation catalyst				1		1
	4. Tier 0	3			1		4
	5. Tier 1	1			1		2
LNG Total		4			3		7
LPG	1. Non-catalyst			1			1
	2. Oxidation catalyst		1	3		3	7
	3. 3-way catalyst		2		4	1	7
	4. Tier 0	4	2	9	1	2	18
	5. Tier 1	1		6	1	7	15
LPG Total		5	5	19	6	13	48
M85	4. Tier 0	1					1
M85Total		1					1
Missing	1. Non-catalyst	6	1				7
	2. Oxidation catalyst	5	3				8
	3. 3-way catalyst	15					15
	4. Tier 0	88		5			93
	5. Tier 1	275	2	25			302
	6. NLEV	9		1			10
Missing Total		398	6	31			435
Grand Total		71758	27384	19978	6805	2689	128614

Table 2–18: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	128,614	0	1901	2003	1992	6.73
Cylinders	128,614	0	0	14	5.76	1.58
Displacement (L)	128,614	0	0.00	93.40	3.48	1.86
Ambient Humidity (%)	80,529	48,085	6.41	99.39	34.41	13.61
Ambient Pressure	80,529	48,085	23.47	25.68	24.59	0.27
Ambient Temperature (F)	80,529	48,085	-43.13	79.67	6.40	7.31
Horsepower	88,773	39,841	3.80	28.70	10.01	2.78
Curb Weight (lbs)	0	128,614	.	.	.	.
Inertia Weight (lbs)	88,773	39,841	1500	6500	3291.07	723.31
Odometer	128,614	0	0	999999	88117.33	72437.84

Documentation rating: A. Fully Documented
Multiple documents exist for Colorado's Air Care project detailing the entire project. Supporting documentation and information can be downloaded at the program web site http://www.aircarecolorado.com (last verified October 24, 2002) as well as the Colorado Department of Health and Environment web site at http://www.cdphe.state.co.us/ap/aphom.asp (last verified October 24, 2002). One of the reports of interest is:

1. *Report to the Colorado General Assembly on the Vehicle Emissions Inspection and Maintenance Program.* Submitted to the Colorado General Assembly by the Colorado Air Quality Control Commission on July 1, 2002.

Completeness rating: C. Missing Data
The Air Care program did not record all of the data fields listed as being of interest in Appendix A. The fuel parameters were not included and all tests were conducted with whatever fuel was in the vehicle when it arrived at the testing facility (tank fuel).

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3.0 Special Studies

3.1 Overview

Along with the state I/M programs, we have contacted several labs throughout the US and Canada that perform vehicle emissions testing for a variety of different purposes and studies. While many of the studies were confidential to the clients that they were performed for, there was still a wide range of data that could be made available for public release. All publicly available data that contains second by second emissions testing was examined for possible inclusion into the MSOD. The following four tables show summary information and analysis for data received from all of the special studies.

Table 3-1: Population of Special Studies

Source Description	# Vehicles	# Tests
California Air Resources Board	42	51
University of California CE-CERT	344	878
Coordinating Research Council	12	510
Environment Canada	5	47
North Carolina State University	7	787
New York IPA	6897	18038
West Virginia University	130	2128
Grand Total	7437	22439

Table 3-2: Number of Tests for Each Vehicle Type from Special Studies

Vehicle Type	Model Year Group							Grand Total
	Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
LDV	24	27	1152	9268	5733	99		16303
LDT	6	7	169	1929	1805	36	142	4094
HDT							1342	1342
Bus					47		640	687
Missing							4	4
Grand Total	30	34	1321	11197	7585	135	2128	22430

Table 3-3: Number of Tests for Each Mileage Grouping from Special Studies

Mileage	Vehicle Type	Model Year Group							Grand Total
		Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
Mileage < 50K	LDV	11	15	63	611	3388	99		4187
	LDT	4	3	15	138	853	36		1049
Mileage < 50K Total		15	18	78	749	4241	135		5236
Mileage > 50K	LDV	13	12	1089	8657	2344			12115
	LDT	2	4	154	1791	945			2896
Mileage > 50K Total		15	16	1243	10448	3289			15011
Missing	LDV					1			1
	LDT					7		142	149
	HDT							1342	1342
	Bus					47		640	687
	Missing							4	4
Missing Total						55		2128	2183
Grand Total		30	34	1321	11197	7585	135	2128	22430

Table 3-4: Number of Tests for Each Fuel Type from Special Studies

Fuel	Model Year Group							Grand Total
	Non-catalyst	Oxidation catalyst	3-way catalyst	Tier 0	Tier 1	NLEV	Missing	
CNG					8			8
GASOLINE	30	34	1321	11197	7028	135		19745
LSD					6			6
TOSCO					4			4
ULSD					14			14
GAS (Sulfur modified)					510			510
CARB							479	479
CECD1							127	127
CNG							157	157
Diesel #1							14	14
Diesel #2							536	536
ECD							402	402
FT							35	35
Gasoline							26	26
LNG							129	129
M100							42	42
MG							44	44
MG50D250							54	54
ULSD1							83	83
Missing					15			15
Grand Total	30	34	1321	11197	7585	135	2128	22430

3.2 California Air Resources Board

As part of the California Air Resources Board (CARB) development of the Emission Factor (EMFAC) model, they have developed adjustments to EPA's Unified Cycle (UC). These adjustments, entitled Unified Correction Cycles (UCC) are based off of route specific driving data representative of driving within the Los Angeles area in 1992. CARB then updated the UCC's in 1996 to account for changes in driving patterns. After developing 8 new driving cycles, they conducted an emissions testing program to generate new factors for their EMFAC model.

For this emissions testing program they recruited approximately 81 vehicles from the general fleet population and tested them using the 8 new UCCs, an FTP, and an UC test. Only a portion of the testing data was available for inclusion into the MSOD. Each vehicle's fuel tank was emptied and refilled with Phase I summertime gasoline fuel prior to preconditioning and testing. Second by second data was collected for the UCC and UC tests only [1, 2].

Summary statistics for CARB data appear in the tables below.

Table 3–5: Number of Vehicles for each Vehicle Type

Model Year Group	Vehicle Type			Grand Total
	LDGV	LDT	MDV	
1. Non-catalyst	1			1
2. Oxidation catalyst	1			1
3. 3-way catalyst	7	2		9
4. Tier 0	21	6		27
5. Tier 1	2	1	1	4
Grand Total	32	9	1	42

Table 3–6: Number of Vehicles for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type			Grand Total
		LDGV	LDT	MDV	
Mileage < 50K	4. Tier 0	3	4		7
	5. Tier 1	2	1	1	4
Mileage < 50K Total		5	5	1	11
Mileage > 50K	1. Non-catalyst	1			1
	2. Oxidation catalyst	1			1
	3. 3-way catalyst	7	2		9
	4. Tier 0	18	2		20
Mileage > 50K Total		27	4		31
Grand Total		32	9	1	42

Table 3–7: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	42	0	1973	1994	1988	4.55
Cylinders	42	0	2	8	5.19	1.53
Displacement (L)	42	0	1.14	5.73	2.83	1.16
Ambient Humidity (%)	0	42	.	.	.	.
Ambient Pressure	0	42	.	.	.	.
Ambient Temperature (F)	0	42	.	.	.	.
Horsepower	42	0	5.60	15.90	8.80	2.45
Curb Weight (lbs)	0	42	.	.	.	.
Inertia Weight (lbs)	42	0	2250	5500	3369.05	670.57
Odometer	42	0	22085.00	332391.00	87786.90	54091.94

Documentation rating: A. Fully Documented
This project is documented by two main papers, which are shown below. General information about the California Air Resources Board can be found at url:http://www.arb.ca.gov/msei/msei.htm (last verified October 24, 2002).

1. *Development of Unified Correction Cycles* written by Robert Gammariello and Jeffrey R. Long, submitted to the Sixth CRC On-Road Vehicle Emissions Workshop in March 1996.

2. *Memorandum: Unified Correction Cycles Test Plan.* Written July 19, 2995 by Mark Carlock to Raphael Susnowitz.

Completeness rating: C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. The test program did not record any OBD data and the only fuel information is Phase I summertime.

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3.3 Coordinating Research Council

The Coordinating Research Council (CRC) conducted studies in 1997 to determine the effects of sulfur levels in fuel on vehicles. They used approximately 12 vehicles as shown in Table 3-8. Each vehicle was first tested with approximately 10,000 miles on the odometer. The catalysts were then rapidly aged to the equivalent of over 100,000 miles and retested. To investigate the effects of sulfur, they varied the amount of sulfur in two base fuels by adding the

Auto/Oil 3-component sulfur mixture. They used Federal RFG base fuel with 40, 100, 150, 330, and 600 ppm Sulfur as well as California Phase 2 RFG with 40 and 150 ppm sulfur [1, 2, 3].

Summary statistics for CRC data appear in the tables below.

Table 3-8: Vehicle Summary (Two Vehicles of Each Model)

Vehicle Model	Emission Level	Inertia	HP Dynamometer
1997 Ford Taurus	C_LEV	3625 lb.	5.9 hp
1997 Ford Escort	C_LEV	3000 lb.	6.3 hp
1997 Honda Civic	C_LEV	2750 lb.	7.5 hp
1997 Nissan Sentra	C_LEV	2750 lb.	6.7 hp
1997 Toyota Camry	C_LEV	3375 lb.	7.4 hp
1997 Geo Metro	C_LEV	2375 lb.	7.3 hp

Table 3–9: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	510	0	1997	1997	1997	0
Cylinders	510	0	4	7	4.34	0.76
Displacement (L)	510	0	1.30	3.00	1.96	0.56
Ambient Humidity (%)	510	0	31.48	57.95	44.53	4.38
Ambient Pressure	510	0	97.76	99.36	98.51	0.29
Ambient Temperature (F)	510	0	70.20	78.60	73.92	1.28
Horsepower	510	0	5.90	7.50	6.83	0.60
Curb Weight (lbs)	0	510	.	.	.	.
Inertia Weight (lbs)	510	0	2375	3630	2983.73	421.34
Odometer	509	1	1066	15075	10825.06	2113.76

Documentation rating: B. Can be documented

A full project report detailing the test methods and analysis was not found for the E-47 and E-42 at the time this report was published. Documentation appears in the test records and subsequent analysis. The CRC main web site is at http://www.crcao.com/ (last verified October 24, 2002). Some of the documentation that was available is as follows:

1. *AAMA / AIAM Study on the Effects of Fuel Sulfur on Low Emission Vehicle Criteria Pollutants.* December 1997.

2. ReadMe file included with the data entitled *CRC Project E-47 Sulfur Reversibility Program CD-ROM Description.*

3. ReadMe file included with the data entitled *CRC Certified-LEV Vehicle Fuel Sulfur Effects Emissions Program.*

Completeness rating: C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. OBD parameters are not available from this project.

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3.4 Environment Canada

The Environmental Technology Centre (ETC) at Environment Canada has been conducting a wide range of vehicle testing for many years on both heavy and light duty vehicles and has been collecting second by second data during the vast majority of tests. We have been in discussions with the staff of ETC to determine which of their data sets could be added to the MSOD. At the time this interim report was written, these discussions were still on going and only a very small portion of the potential data had been delivered for use. This section will discuss the data from the two studies that have already been delivered. While it is likely that additional data will be delivered in time for inclusion in this project, all other data is discussed further in Section 4.3 as data for future collection.

The two studies that Environment Canada has already provided for use in the MSOD examined emissions from 40 foot Orion V transit buses from the New York City Transit Authority. The first study examined the emissions from 3 buses, all of which use compressed natural gas. The buses were tested at Environment Canada's testing facility and exhaust emissions were measured while the buses were operated over the Central Business District (CBD) and New York Bus (NYBUS) cycles [1].

The second study examined the performance and durability of continuously regenerating particulate filters for diesel-powered buses. In this study 25 New York City transit buses were equipped with continuously regenerating diesel particulate filter systems for 9 to 12 months. As part of this study, two of the buses were selected for in-depth exhaust emissions testing before and after the particulate filter systems were in use. The buses were tested operating over the CBD and NYBUS cycles and were tested operating on New York standard diesel fuel #1 (300 ppm sulfur) as well as ultra low sulfur diesel (<30 ppm sulfur) [2].

Details of the buses used in both studies appear in Table 3-10 and 3-11. No data is available for the ambient test conditions.

Table 3-10: Bus Characteristics

Detail	Value
Model – CNG	1999 DDC Series 50 G
Model - Diesel	1999 DDC Series 50
Chassis	New Flyer CLF 40
Displacement	8.5L
Type	4-Stroke
Power (hp)	275
Configuration	Inline 4 cylinder

Table 3–11: Number of Tests for Each Fuel Type

Fuel	Number of Test
Compressed Natural Gas	8
Low Sulphur Diesel	6
TOSCO (Ultra Low Sulphur Diesel)	4
Ultra Low Sulphur Diesel	14
Missing	15
Grand Total	47

<u>Documentation rating:</u> A. Fully Documented
Two main papers, as shown below, document the projects. Additional information about Environment Canada can be found at http://www.etcentre.org/etchome_e.html (last verified October 24, 2002).

1. *Determination of Exhaust Emissions from Three New York City Transit CNG Buses.* ERMD Report #01-34. Prepared by Environmental Technology Centre, Emissions Research and Measurement Division in 2001.

2. Chatterjee, *et al. Performance and Durability Evaluation of Continuously Regenerating Particulate Filters on Diesel Powered Urban Buses at NY City Transit – Part II.* Society of Automotive Engineers, Inc. Report number 2002-01-0430, written in 2002.

<u>Completeness rating:</u> C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. None of the ambient test conditions were recorded.

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3.5 New York Instrumentation Protocol Assessment

New York State runs a decentralized inspection and maintenance (I/M) program that does not use the EPA standard IM240 protocol, but instead uses a New York Transient Emissions Short Test (NYTEST) testing program and equipment. To support this substitution in testing programs, New York has been performing a comparison study between the NYTEST and IM240 emissions test. This study is entitled *Evaluation of Simultaneous Emissions Test Data Derived From the NYTEST Instrumentation/Protocol Assessment Pilot Study*. The study is referred to as the IPA. This study began as a pilot study in 1998 and has been carried on yearly ever since.

During the IPA study, vehicles are simultaneously tested using both the NYTEST and IM240 equipment. The composite results are then analyzed for equivalency. All tests were performed by TESTCOM contractors at one testing facility. The vehicles used during the testing were recruited from the general vehicle fleet population and were roughly followed the distribution fleet age distribution. Tank fuel (gasoline) was used for all vehicles. Second by second data has been made available for all years of the IPA program for the IM240 testing [1, 2, 3].

Summary statistics for the New York IPA program data appear in the tables below.

Table 3–12: Number of Tests for each Vehicle Type

Model Year Group	Vehicle Type		Grand Total
	LDV	LDT	
2. Oxidation catalyst	3	0	3
3. 3-way catalyst	1089	121	1210
4. Tier 0	9004	1772	10776
5. Tier 1	4424	1490	5914
6. NLEV	99	36	135
Grand Total	14619	3419	18038

Table 3–13: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type LDV	LDT	Grand Total
Mileage < 50K	3. 3-way catalyst	3	55	58
	4. Tier 0	111	536	647
	5. Tier 1	686	2166	2852
	6. NLEV	36	99	135
	Mileage < 50K Total	836	2856	3692
Mileage > 50K	2. Oxidation catalyst	0	3	3
	3. 3-way catalyst	118	1034	1152
	4. Tier 0	1661	8468	10129
	5. Tier 1	804	2258	3062
	Mileage > 50K Total	2583	11763	14346
	Grand Total	3419	14619	18038

Table 3–14: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	18,038	0	1,980	2,001	1,992	4
Cylinders	18,038	0	0	8	5	1
Displacement	0	18,038	.	.		
Ambient Humidity	18,038	0	0	92	35	13
Ambient Pressure	0	18,038	.	.		
Ambient Temperature	0	18,038	.	.		
Horsepower	18,038	0	1	27	14	3
Curb Weight	0	18,038	.	.		
Inertia Weight	18,038	0	1,750	6,000	3,323	583
Odometer	18,038	0	239	1,255,864	91,199	52,486

Documentation rating: A. Fully Documented
The program is fully documented in several reports. Some of the primary reports are as follows:

1. *Evaluation of Simultaneous Emissions Test Data Derived From the NYTEST Instrumentation/Protocol Assessment Pilot Study, Regression and Residual Analysis of NYTEST and IM240 Composite Emission Test Results.* Prepared by the New York State Department of Environmental Conservation Division of Air Resources Bureau of Enhanced Inspection and Maintenance & the Automotive Emissions Laboratory, May 2000.

2. *Amendments 1 and 2 Project Summary Report (Emissions Data Collected in 1999 and 2000),* prepared by the New York State Department of Environmental Conservation Division of Air Resources Bureau of Enhanced Inspection and Maintenance & the Automotive Emissions Laboratory, January 2002.

3. *IPA Amendment #3 Project Summary Report*. Prepared by the New York State Department of Environmental Conservation Division of Air Resources Bureau of Enhanced Inspection and Maintenance & the Automotive Emissions Laboratory, July 2002.

Completeness rating: C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. OBD and fuel parameters are not available from this project.

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3.6 North Carolina State University

In 2001 Dr. Christopher Frey from the Department of Civil Engineering at North Carolina State University headed a team to investigate the emissions reductions that could be achieved through improvement in traffic management. They used the portable exhaust gas analyzer, OEM-2100™, from Clean Air Technologies International, Inc. to collect on-road vehicle emissions. This instrumentation was attached to a small number of vehicles that were then repeatedly driven on predefined routes.

Two main sites were used for the study, Chapel Hill Road and Walnut Street in North Carolina. The vehicles used at each site appear in Table 3-15. A small number of drivers were used to ensure repeatability in the driving behavior. Regular unleaded gasoline was used for all vehicle runs and no further fuel information is available from the study [1].

Summary statistics for the North Carolina data appear in the tables below

Table 3-15: Vehicles used in NCSU Study

Vehicle	Chapel Hill Road	Walnut Street
1999 Ford Taurus	Primary	Primary
1998 Chevrolet Venture Minivan	Primary	(not used)
1998 Toyota Camry	Secondary	Secondary
1998 Dodge Caravan	Secondary	Secondary
1997 Jeep Cherokee	Secondary	(not used)
1996 Oldsmobile Cutlass	Secondary	Primary

Table 3–16: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type LDV	LDT	Grand Total
Mileage < 50K	5. Tier 1	592	77	669
Mileage > 50K	5. Tier 1		111	111
Missing	5. Tier 1		7	7
	Grand Total	592	195	787

Table 3–17: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	787	0	1996	1999	1998	1.25
Cylinders	0	787	.	.	.	.
Displacement (L)	767	20	0.30	4.00	2.80	0.56
Ambient Humidity (%)	671	116	20.00	97.00	48.46	21.07
Ambient Pressure	0	787	.	.	.	.
Ambient Temperature (F)	745	42	28.00	95.00	61.12	15.96
Horsepower	0	787	.	.	.	.
Curb Weight (lbs)	727	60	1063	5357	4495.97	741.67
Inertia Weight (lbs)	0	787	.	.	.	.
Odometer	780	7	30875	83260	41397.46	10395.85

Documentation rating: A. Fully Documented
The project is well documented in its final report. The report and additional information can be downloaded from NCSU's website http://www4.ncsu.edu/~frey/ (last verified on October 24, 2002).

1. Frey, *et. al. Emissions Reduction Through Better Traffic Management: An Empirical Evaluation Based Upon On-Road Measurements.* Prepared for the North Carolina Department of Transportation, December 2001.

Completeness rating: C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. The project used regular unleaded gasoline and did not record any further fuel parameters.

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3.7 University of California CE-CERT

Researchers at the University of California College of Engineering-Center for Environmental Research and Technology (CECERT) have been conducting a variety of vehicle test programs for several years. After discussions with the CE-CERT staff, data from two of their test programs were submitted for inclusion into the MSOD. These two test programs are discussed below. Several other studies performed at CE-CERT appear to be of interest but were not available within the time frame of this project and are discussed further in Section 4.5.

3.7.1 Comprehensive Modal Emissions Model

Data was collected by CECERT for the modal emissions model development program. This program can best be described through the following excerpt taken from the report *NCHRP Project 25-11 Development of a Comprehensive Modal Emissions Model final Report* written by Matthew Barth and associates in April 2000.

> In August 1995, the College of Engineering-Center for Environmental Research and Technology (CECERT) at the University of California-Riverside along with researchers from the University of Michigan and Lawrence Berkeley National Laboratory, began a four-year research project to develop a *Comprehensive Modal Emissions Model (CMEM)*, sponsored by the National Cooperative Highway Research Program (NCHRP, Project 25-11). The overall objective of the research project was to develop and verify a modal emissions model that accurately reflects Light-Duty Vehicle (LDV, i.e., cars and small trucks) emissions produced as a function of the vehicle's operating mode. The model is comprehensive in the sense that it is able to predict emissions for a wide variety of LDVs in various states of condition (e.g., properly functioning, deteriorated, malfunctioning). The model is now complete and capable of predicting second-by-second tailpipe emissions and fuel consumption for a wide range of vehicle/technology categories. In creating CMEM, over 350 vehicles were extensively tested on a chassis dynamometer, where second-by-second measurements were made of both engine-out and tailpipe emissions of carbon monoxide, hydrocarbons, oxides of nitrogen, and carbon dioxide. CMEM itself runs on a personal computer or on a UNIX workstation. The model and the emissions database are both available on a CD [1].

The vehicles used in the study were typically tested with three test cycles: 3-bag Federal Test Procedure (FTP), US06 cycle (bag 4 of the supplemental FTP), and a second by second emissions cycle developed by CECERT entitled the Modal Emission Cycle (MEC). The MEC was designed to cover a range of driving modes including steady-state cruise, accelerations, decelerations, and idle. All vehicles were recruited out of the general vehicle population and whatever gasoline that they had in their tanks was used during testing.

Summary statistics for the NCHRP data appear in the tables below.

Table 3–18: Number of Test for Each Vehicle Type

Model Year Group	Vehicle Type		Grand Total
	LDV	LDT	
1. Non-catalyst	23	6	29
2. Oxidation catalyst	23	7	30
3. 3-way catalyst	56	46	102
4. Tier 0	243	151	394
5. Tier 1	205	118	323
Grand Total	550	328	878

Table 3.–19: Number of Tests for Each Mileage Grouping and Vehicle Type

Mileage	Model Year Group	Vehicle Type		Grand Total
		LDV	LDT	
	1. Non-catalyst	11	4	15
	2. Oxidation catalyst	15	3	18
Mileage < 50K	3. 3-way catalyst	8	12	20
	4. Tier 0	72	23	95
	5. Tier 1	119	88	207
	Mileage < 50K Total	225	130	355
	1. Non-catalyst	12	2	14
	2. Oxidation catalyst	8	4	12
Mileage > 50K	3. 3-way catalyst	48	34	82
	4. Tier 0	171	128	299
	5. Tier 1	86	30	116
	Mileage > 50K Total	325	198	523
	Grand Total	550	328	878

Table 3–20: Statistics for Numerical Data Fields

Variable	Count	Missing	MIN	MAX	MEAN	STD
Model Year	878	0	19	1999	1966	219
Cylinders	878	0	3	8	5	2
Displacement	878	0	0	8	2.55	1.90
Ambient Humidity	878	0	0	88	48.33	24.01
Ambient Pressure	878	0	0	30	23.40	11.25
Ambient Temperature	878	0	0	93	67.79	21.72
Horsepower	878	0	0	29	9.18	6.78
Curb Weight	. 0	878	.	. .		
Inertia Weight	878	0	1750	8000	3333.86	778.19
Odometer	878	0	96	228988	67774.06	47422.64

Documentation rating: A. Fully Documented
The project is well documented in its final report cited below. Additional information can also be found on their web site at http://www.cert.ucr.edu.

1. Matthew Barth, *et. al. NCHRP Project 25-11 Development of a Comprehensive Modal Emissions Model Final Report* April 2000.

Completeness rating: C. Missing Data
This program did not record all of the data fields listed as being of interest in Appendix A. The project used whatever fuel was in the vehicle at the time of recruitment (tank fuel) and did not record any OBD information.

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3.7.2 CE-CERT Ammonia Study

In 2001 CE-CERT conducted a study to examine the factors that influence ammonia emissions from light-duty cars and trucks. During this study they tested 39 vehicles on the FTP driving cycle. The manufacturer of these vehicles is shown below in Table 3-21. All of these tests were performed with whatever gasoline was in the vehicle tank at the time that the vehicle was procured. During each test they recorded the standard exhaust measurements along with utilizing Fourier transform infrared spectroscopy to measure the ammonia emissions. They also performed additional testing on five vehicles using the US06, the New York City Cycle (NYCC), and a high-speed freeway cycle in order to determine effects of driving patterns on ammonia emissions. Finally, two vehicles were tested using gasoline with 30 and then 330 ppmw sulfur levels to investigate the effects of fuel sulfur levels.

Table 3-21: Vehicles Used In Ammonia Study

Manufacturer	LDV (car)	LDT
GM	3	9
Ford	4	5
Chrysler	3	1
Honda	6	0
Toyota	2	2
Nissan	2	0
Other	1	1

Documentation rating: Undetermined
At the time this report was written CE-CERT was still in the process of submitting their data. A final determination will be made once the data has been transferred and reviewed. The above discussion was taken from the following reports:

1. Thomas D. Durbin, Ryan D. Wilson, Joseph M. Norbeck, J. Wayne Miller, Tao Huai, Sam H. Rhee, *Estimates of the emission rates of ammonia from light-duty vehicles using standard chassis dynamometer test cycles.* Atmospheric Environment 36 (2002) 1475 1482. Accepted December 2 2001

Completeness rating: Undetermined
A full determination of the completeness of the data could not be made because the actual data had not been received by the time this report was written.

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3.8 West Virginia University

In 1992 West Virginia University (WVU) developed two transportable chassis dynamometer laboratories for testing heavy duty vehicles. Each dynamometer is set up on a flat-bed trailer and is designed to allow a heavy duty truck or bus to be driven onto it and tested. The rollers of the dynamometer are free rotating and are not used to absorb any load. Instead, power is taken directly from the drive wheels through an adapter which couples it to a flywheel, which simulates inertial load, and eddy current power absorbers, which simulate road load. The exhaust gas is ducted to a dilution tunnel and from there sample pipes bring the exhaust into the analyzers [1, 2].

WVU has used this equipment to conduct numerous studies for both private and public organizations. At the time that this report was written EPA was in the process of procuring part of this data from three testing sites for inclusion into the MSOD and only summary information was available for this data. The following tables show a review of the type of testing performed at the three different sites. The remainder of the data collected from WVU is either confidential or outside the time frame of this project to procure and is summarized in Section 4.4.

Summary statistics for WVU data appear in the tables below.

Table 3–22: Testing Activity at Each Site

Site	Abbreviation	Vehicles	Tests
Ralph's Grocery	RAGRO	85	1098
Washington Metropolitan Area Transit Authority	WMA	10	97
West Virginia University	WVU	35	933
Grand Total		130	2128

Table 3–23: Number of Tests for Each Vehicle Type Tested

Vehicle Type	Facility			Grand Total
	RAGRO	WMATA	WVU	
Beverage Truck	6			6
box truck	62		43	105
Chassis Bus			118	118
Flat Bed	4			4
Fuel Cell Bus			42	42
Fuel Truck	65			65
Hybrid Elec Transit Bus	16			16
Pick-Up Truck			68	68
Refuse Truck	284		128	412
School Bus	57			57
Suburban			70	70
Tractor	40			40
Tractor Truck	469		239	708
Transit Bus	91	97	219	407
truck			2	2
VAN	4			4
Missing			4	4
Grand Total	1098	97	933	2128

Table 3–24: Number of Tests for Each Fuel Type Used

Primary Fuel ID	Facility			Grand Total
	RAGRO	WMATA	WVU	
CARB	479			479
CECD1	119		8	127
CNG	35		122	157
D1 Diesel		14		14
D2 Diesel	11		525	536
ECD	402			402
FT	10		25	35
GSLN	16		10	26
LNG	26		103	129
M100			42	42
MG			44	44
MG50D250			54	54
ULSD1		83		83
Grand Total	1098	97	933	2128

Table 3–25: Number of Tests for Each Drive Cycle Used

Cycle full name	Facility			Grand Total
	RAGRO	WMA	WVU	
14 Peak Cycle			12	12
14 Peak Route			24	24
Alternative 1			1	1
Alternative 2			1	1
Arterial Cycle			27	27
CARB HHDDT Transient Mode			15	15
Central Business District Cycle	5		256	261
Central Business District Route			5	5
City Cycle			1	1
City Suburban Cycle			5	5
City Suburban Route	314		59	373
Coast Down			2	2
Cold Start Extended CBD Cycle		8		8
Cold Start William H. Martin Cycle			5	5
D Cycle	29		38	67
Double CSHVR Route	143			143
Double Length 5Miles Cycle	103		4	107
Double Manhattan Cycle	6			6
Double New York Garbage Truck Cycle	48			48
Double Test D with Warmup	18			18
Double Urban Dynamometer Driving Schedule	5			5
Double Washington DC Metro Transit Bus Cycle		24		24
Double WHM Cycle			11	11
Federal Test Procedure			4	4
FIGE			1	1
FTP-75			59	59
Georgetown University TS			4	4
Hiway Cycle	34		3	37
Idle State Cycle	36		19	55
Lug Down			2	2
Manhattan	12			12
Modified WVU Truck Cycle (Route)			34	34
Morgantown On-road Cycle			19	19
New York Bus Cycle			2	2
Orange County Refuse Truck Cycle	62			62
Orange County Transit Authority Bus Cycle	27			27
Steady State Cycle - 20MPH			4	4
Steady State Cycle - 30MPH			6	6
Steady State Cycle - 40MPH			10	10
TCDC			6	6

Table continued on next page.

Table 3–26: Drive Cycles Used During Testing (Continued)

Cycle full name	Facility			Grand Total
	RAGRO	WMA	WVU	
Test D Route			2	2
Triple CBD No Warm up	12			12
Triple Length CBD	174	19	28	221
Triple New York Bus Cycle	17			17
Unknown	38		197	235
US06			4	4
Viking Freight Adhoc Cycle	15			15
Washington DC Metro Transit Bus Cycle		46		46
WHM Cycle			35	35
WVU 1 Peak Cycle			4	4
WVU Truck Cycle (5 Peak)			20	20
Yard Cycle			4	4
Grand Total	1098	97	933	2128

Documentation rating: Undetermined
At the time this report was written EPA was still in final negotiations to procure the data from WVU. A final determination will be made once the data has been transferred and reviewed. The above discussion was taken from the following reports:

1. Ramamurthy, Clark, Atkinson, and Lyons. *Models for Preedicting Trnasient Heavy Duty Vehicle Emissions*, SAE Technical Paper Series number 982652, Reprinted from Diesel Emissions (SP-1397), 1998.

2. Clark, Prucz, Gautam, and Lyons. *The West Virginia University Heavy Duty Vehicle Emissions Database as a Resource for Inventory and Comparative Studies.* SAE Technical Paper Series number 2000-01-2854, Reprinted From Diesel Aftertreatment (SP-1561), 2000.

Completeness rating: Undetermined
The actual data had not been received by the time this report was written and so a full determination of the completeness of the data could not be made.

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4.0 Other Possible Sources of Data for Future Collection

4.1 Overview

During the course of this investigation there were several collections of data that appeared highly desirable for inclusion into the MSOD but were unavailable given the time frame of this project. Several of the data sources mentioned above in this report were able to provide only a portion of their data for this project and would most likely be able to provide additional data given more time and funding. These additional data collections are briefly discussed below for possible future review and investigation.

4.2 Coordinating Research Council

The Coordinating Research Council is currently conducting several studies that would most likely be highly beneficial for inclusion into the MSOD upon their conclusion. Each of these studies collects second by second data. Below is a brief summary of each study.

E-55 Heavy Duty Vehicle Chassis Dynamometer Testing For Emission Inventory

This study evaluated the Heavy Heavy-Duty Diesel Truck (HHDT) cycle developed by ARB for representativeness and repeatability. After the evaluation, CRC made recommendations for modifications and the creation of a new schedule. This new schedule was then used by staff from West Virginia University (WVU) to test two class 8 tractors of different model years and manufacturers (Ford and Mack). New test procedures were developed during the course of their testing and a final set of tests were performed using the finalized procedures. The emission results from the tests were then used to review and assess the accuracy of emissions factors used in mobile source inventory models [1].

E-60 Ammonia Emissions From Late Model Vehicles

This project will examine the effects of the use of ultra-low sulfur fuel on exhaust emissions of ammonia. The project will test 12 vehicles that have at least 10-20,000 miles of customer driving only in California. The targeted vehicles for testing are shown in table 4-1 below.

Table 4-1: Targeted Vehicles for Testing [2]

MY	OEM	Model	Certification	Displacement	Engine Family
2000	Chrysler	Sebring Conv.	LEV	2.5 L	?
1999	Ford	Taurus	LEV	3.0 L	XFMXV03.0VGC
1999	Olds	Alero	LEV	2.4 L	XGMXV02.4027
1999	Chevy	Silverado	LEV	5.3 L	XGMXA05.3183
1999	Ford	Windstar	ULEV	3.8 L	YFMXT03.82JC
2000	Jeep	Grand Cherokee	LEV	4.7L	?
2000	Buick	Le Sabre	ULEV	3.8 L	YGMXV03.8901
2000	Dodge	Neon	ULEV	2.0 L	YCRXV0122V40
2000	Acura	3.2 TL	ULEV	3.2 L	YHNXV03.2GL4
2000	Toyota	Camry	ULEV	2.2 L	YTYXV02.2JJB
2000	Honda	Accord	SULEV	2.3 L	YHNXV02.3NL5
2000	Nissan	Sentra CA	SULEV	1.8 L	YNSXV01.85BA

Each vehicle will be repeatedly tested using the standard FTP and US06 test procedures, with additional steps taken to measure ammonia emissions. All testing will be performed using California Phase 2 base gasoline with sulfur levels of 1, 30 and 150 ppm [2].

E-61 Impact of Engine Oil Properties on Emissions

The following excerpt was taken from the final report of this project and describes the intent of the project as well as the type of testing performed [3]. Table 4-2 below, also taken from the final report, shows the vehicles that were used in this project.

> The objective of the present program was to determine whether sulfur levels in engine oil could have a measurable impact on vehicle emissions. For this study, the emissions impact of oil sulfur was evaluated for 4 ultra-low-emission vehicles (ULEVs) and 2 super-ultra-low-emission vehicles (SULEVs) using oils with sulfur contents ranging from 0.01% to 0.76% and a gasoline with a 0.2 ppmw sulfur content. Vehicles were configured with aged catalysts and tested in triplicate over the Federal Test Procedure (FTP) and at idle and 50 miles per hour (mph) cruise conditions. In addition to the regulated emissions and modal engine-out and tailpipe emissions, engine-out SO2 was measured in near real-time using a novel approach with a differential optical absorption spectrometer (DOAS) [3].

Table 4-2: Description of Test Vehicles [3]

MY	OEM	Model	Certification	Displacement	Mileage	Engine Family
2001	Ford	Windstar	ULEV	3.8 L	20,407	1FMXT03.82JX
2001	Buick	LeSabre	ULEV	3.8 L	16,308	1GMXV03.8044
2001	Dodge	Neon	ULEV	2 L	17,769	1CRXV0122V40
2001	Toyota	Camry	ULEV	2.2 L	20,678	1TYXV02.2JJA
2000	Honda	Accord	SULEV	2.3 L	10,548	YHNXV02.3NL5
2001	Nissan	Sentra CA	SULEV	1.8 L	5,237	1NSXV01.852A

References:
1. Gautam, Clark et all. *Final Report, Qualification of the Heavy Heavy-Duty Diesel Truck Schedule and Development of Test Procedures.* CRC Project No. E-55-2. Submitted by West Virginia University Research Corporation. March, 2002.

2. *Draft Scope of Work, CRC Project No. E-60, Ammonia Emissions from Late Model Vehicles.* August 30, 2000.

3. Dubin et all. Final Report, Impact of Engine Oil Properties on Emissions, *CRC Project No. E-61*. Prepared for the Coordinating Research Council. Submitted August 2002.

4.3 Environment Canada

As discussed in Section 3.4 above, we were unable to procure the majority of data that is of interest from the Environmental Technology Centre (ETC) at Environment Canada by the time this report was written. Much of the data will require additional work by the ETC staff to reformat it for public use. A list of some of the studies of interest along with the year that they were performed appears below.

- 1994 Nitrous Oxide Emissions from Light Duty Vehicles - Phase 1
- 1994 The Effects of Aged Catalysts and Cold Ambient Temperatures on Nitrous Oxide Emissions
- 1995 Evaluation of Biodiesel in an Urban Transit Bus Powered by a 1988 DDC6V92 Engine
- 1995 Evaluation of Biodiesel in an Urban Transit Bus Powered by a 1981 DDC8V71 Engine
- 1995 Evaluation of Tall Oil Biodiesels on Diesel Engine Exhaust Emissions
- 1996 Study of HD Vehicle Exhaust Emissions from a Modified CNG Bus Fueled with Hythane
- 1998 Investigation of Potential exhaust emission Reductions through the use of Biodiesel used in Conventional Diesel Engines.
- 1998 Evaluation of Emissions and Fuel Economy of the Hybrid Nova Bus
- 1998 HD Diesel Engine Exhaust Emissions of Diesel Fuels Derived from Oil Sands and Conventional Crude Oil
- 1999 Evaluation of Emissions & Fuel Economy of the Hybrid Nova Bus
- 1999 Evaluation of Emissions & Fuel Economy of the Hybrid Nova Bus - Phase II
- 2000 Exhaust Emissions Testing of a DDC Series 50 Urban Bus Engine Operating Diesel and PuriNOx
- 2000 Electric Hybrid Bus Exhaust Emissions Study - Part 111

- 2001 Emissions Testing of an Orion Hybrid-Electric Bus installed with Emission Control Devices and Low Speed Bias
- 2001 Measurement and Evaluation of Exhaust Emissions of Urban Transit Buses with Retrofit Exhaust Aftertreatment Equipment

The first two studies on the list above are of particular interest for this project since they were directly examining the factors effecting nitrous oxide emissions from light duty vehicles. The vehicles used in the aged catalyst study appear in Table 4-3 below. Testing was performed with summer and winter grade gasoline [1].

Table 4-3: Vehicles Description [1]

MY	Model	Displacement L	Cylinders	Transmission	Mileage
1988	Ford Taurus	3	6	A4	71883
1988	Chevrolet Beretta	2.8	6	A5	75167
1989	Honda civic Sedan	1.5	4	A4	19583
1989	Toyota Corolla	1.6	4	A5	33016
1989	Chevrolet Astro Van	4.3	6	A4	47152
1989	Honda Civic Hatchback	1.5	4	A5	85420
1990	Mazda 626	2.2	4	A4	20986
1990	Chevrolet Cavalier	2.2	4	A3	21889
1990	Mazda 323	1.6	4	A5	30545
1991	Toyota Corolla	1.6	4	A5	32144
1993	Cherolet Blazer	4.3	6	A4	2279
1993	Dodge Dakota	3.9	6	A4	2365
1993	Oldsmobile Cutlass Ciera	3.3	6	A4	2395
1993	Ford Probe	2	4	A5	2561

References:
1. Barton and Simpson. *The Effects of Aged Catalysts and Cold Ambioent Temperatures on Nitrous Oxide Emissions.* Unpublished MSED Report #94-21, 1994.

4.4 West Virginia University

West Virginia University has testing data available from approximately 40 different testing sites only three of which were readily available for inclusion into the MSOD during this project. While not all of the data can be made publicly accessible due to confidentiality agreements or lost records, there still remains a large amount of valuable heavy duty vehicle testing that could be gathered and added into the MSOD. The following tables briefly summarize the different testing performed by WVU.

Table 4-4: Test Sites

Testing Site	# Vehicles	# Tests
Ag Processing, Inc. Total	12	208
Arco Total	8	80
BI-State Development Agency Total	11	177
Brooklyn Natural Gas Union Total	35	306
Chicago Transit Authority Total	7	66
Dallas Area Rapid Transit Total	16	122
Denver Regional Transit District Total	17	123
Desert Sands Unified School District Total	15	154
EEA Total	50	611
Flint Mass Transit Authority Total	9	57
Greater Peoria Mass Transit District Agency Total	16	335
Houston Metropolitan Transit Authority Total	4	30
Idaho National Engineering Laboratory Total	11	176
Johnson Power Systems Total	17	258
Kanawha Valley Regional Transportation Authority Total	12	67
Massachusetts Bay Transportation Authority Total	12	94
Mayflower Transit Total	6	25
Metro Council Transit Operations Total	27	394
Metro Dade Transit Agency Total	26	301
Metropolitan Atlanta Rapid Transit Authority Total	14	87
Metropolitan Suburban Bus Authority Total	20	140
Miami Valley Regional Transit Agency Total	7	32
New York City Command Bus Company Total	75	639
New York City DEP Mobile Systems Units Total	8	45
Northrop Advanced Technology Transit Bus Program Total	2	22
Orange County Transportation Authority Total	14	103
Paul Revere Transportation LLC Massport Total	17	211
Phoenix Transit System Total	18	239
Pierce County Public Transportation Total	24	192
Port Authority of Allegheny County Total	12	106
Queens Surface Corp. Total	2	37
Raley's Distribution Center Total	14	201
Rhone Poulenc of Mexico, S. A. Total	12	92
Southwest Ohio Regional Transit Authority Total	11	54
Tri-County Metropolitan Transit District of Oregon Total	17	156
Wood County Schools Bus System Total	5	17
Grand Total	583	5957

Table 4-5: Number of Tests Performed on Each Vehicle Type

Vehicle Type	Count
Articulating Transit Bus	44
Basin Cleaner Truck	11
Box Truck	112
Bus	22
Cable Truck	10
Coca-Cola Truck	68
Dump Truck	41
Experimental Transit Bus	37
Flatbed Truck	12
Fuel Truck	86
Hybrid Bus	6
Parcel Delivery Truck	12
Pick-up Truck	10
Pump Truck	9
Refuse Truck	652
Salt Truck	9
School Bus	221
Service Truck	27
Sewer Cleaner Truck	22
Snow Plow Truck	100
Street Sweeper	12
Tanker Truck	16
Tire Truck	47
Tour Bus	37
Tractor Truck	932
Transit Bus	3317
Trolley Bus	29
Utility Truck	56
Grand Total	5957

Table 4-6: Number of Tests on Each Fuel Type

Primary Fuel ID	Count
BD	87
BD20	57
BD35	52
BD50	5
CAD	74
CARB	37
CD	6
CNG	1352
D1	1370
D1-LS	9
D2	1620
E100	66
E93	24
E95	309
ECD	43
FT-MG	13
FT-SMD	37
FT-SMD50/CAD50	21
GSLN	10
JP4	8
LNG	377
LPG	22
M100	308
MG	13
OXYD1	24
OXYD2	13
Grand Total	5957

Table 4-7: Number of Tests for Each Drive Cycle

Drive Cycle Used	Count
14 Peak Route	19
Arterial Cycle	50
Business Arterial Cycle	75
Central Business District Cycle	3640
Central Business District Route	1
City Suburban Route	88
Coast Down	54
Commute Cycle	40
D Cycle	79
Double CSHVR Route	13
Double Length 5Miles Cycle	18
Double Orange County Refuse Truck Cycle	17
Idle State Cycle	10
Kern Cycle	3
Lug Down	8
Manhattan	27
Modified WVU Truck Cycle (Route)	725
New York Bus Cycle	136
New York Composite Cycle	38
New York Garbage Truck Cycle	146
New York Truck Cycle	8
NYC Street Sweeper Cycle	12
Route22	20
Route77	11
Snap Test	39
Steady State Cycle - 20MPH	110
Steady State Cycle - 30MPH	7
Steady State Cycle - 40MPH	34
Steady State Cycle - 60MPH	2
Test D Route	143
Triple Length CBD	40
Triple New York Garbage Truck Cycle	16
Unknown	2
WVU Truck Cycle (5 Peak)	326
Grand Total	5957

4.5 University of California CE-CERT

The University of California CE-CERT has performed numerous studies of interest that have been pursued during this project for inclusion into the MSOD. Unfortunately, none of the data was available for review in this report. Table 4-8 below shows a listing of the studies that are of most interest and includes any pertinent references for each study that was available.

Table 4-8: CE-CERT Studies

Study Name	Date	Cycles	Comments	Ref.
Effect of payload on emissions of light & heavy duty vehicles	Oct-99	FTP, ST01, CD-arterial	s-b-s CO, HC, NOx, CO2, fuel	1
Particulate Measurement Techniques and instrument characterization	1-Oct	FTP	s-b-s CO, HC, NOx, CO2, fuel, PM	2, 3
OBD II evaluation study	2-Mar	FTP, IM240, ASM	s-b-s CO, HC, NOx, CO2, fuel	4
Biodiesel blends analysis for light heavy duty trucks	2-Aug	FTP	5 fuels	5, 6
ARCO EC-D diesel particulate study	2-Jul	FTP	s-b-s CO, HC, NOx, CO2, fuel, diesel PM	7
EPA NH3 Sulfur study	2-Mar	FTP, STO1, US06	2 sulfur levels, CO, HC, NOx, CO2, fuel, NH3	8
Lubricant Sulfur Analysis	2-Aug	FTP, steady state	s-b-s CO, HC, NOx, CO2, fuel, SO2	9
EPA NH3 Modeling	2-Oct	FTP hot bag 1, MEC01 NYCC	s-b-s CO, HC, NOx, CO2, fuel, NH3	
NH3 from light duty vehicles	2-Dec	FTP, NYCC, US06, highspeed	s-b-s CO, HC, NOx, CO2, fuel, NH3	
Heavy Duty Diesel Truck Study	on going	CARB HDDT cycle, modal cycle	s-b-s CO, HC, NOx, CO2, fuel	
Study for Extremely Low Emitting Vehicles	on going	FTP, US06, MEC01	s-b-s CO, HC, NOx, CO2, fuel	

References:

1. Durbin, Norbeck, Wilson, Galdamez. Effect of Payload on Exhaust Emissions from Light Heavy-Duty Diesel and Gasoline Trucks. Environ. Sci. Technol. 2000, 34, 4708-4713.

2. MoosMuller et all. Time Resolved Characterization of Diesel Particulate Emissions. 1. Insturments for Particle Mass Measurements. Environ. Sci. Technol. 2001, 35, 781-787.

3. MoosMuller et all. Time Resolved Characterization of Diesel Particulate Emissions. 2. Insturments for Elemental and Organic Carbon MEasurements. Environ. Sci. Technol. 2001, 35, 1938-1942.

4. Durbin, Norbeck, Wilson, Smith. Final Report, Evaluation of the Effectiveness of On-Board Biagnostics II (OBDII) in Controlling Motor Vehicle Emissions. May 2001, Sponsored by South Coast Air Quality Management District Technology Advancement Office and The US EPA. 01-VE-22854/20984-001-FR.

5. Durbin, Collins, Norbeck, and Smith. Final Report, Evaluation of the Effects of alternative Diesel Fuel Formulations on Exhaust emission Rates and Reactivity. Contract No. 98102, Submitted to South Coast Air Quality Management District, April 1999. 99-VE-RT2P-001-FR.

6. Durbin, Cocker, Collins and Norbeck. Final Report, Evaluation of the Effects of Biodiesel and biodiesel Blends on Exhaust Emission Rates and Reactivity - 2. Contract No. 99120. Submitted to south Coast Air Quality Management District. August 2001. 01-VE-20998-001-FR.

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4.6 University of Texas

The University of Texas at Austin is currently conducting a study for the Texas Department of Transportation on the use of new fuels in heavy-duty diesel vehicles. The primary purpose of the study is to evaluate new fuels with regard to changes in emissions, maximum power, and fuel economy. Particular types of vehicles being used in the study are dump trucks, wheeled loaders, and telescoping boom excavators. Data of interest to the MSOD consists of activity data and dynamometer emissions data. Second-by-second activity data has been collected on two single axle dump trucks (four weeks total), two tandem axle dump trucks (four weeks total), a telescoping boom excavator (one week), and a wheeled loader (one week) during their normal work activity. Logged quantities include vehicle speed (dump trucks only), RPM, percent torque, and accelerator position. The activity data will be used to build chassis dyno test cycles for the single axle and tandem axle dump trucks and to build engine dyno test cycles for the excavator and loader. The chassis and engine test cycles will then be used to generate second-by-second HC, CO, and NOx emissions data for eight dump trucks and for two diesel engines, respectively.

Appendix A Fields for MSOD

Data Source Documentation
EPA Contract Number 68-C-00-112
Work Assignment Number 2-06

Appendix B : Data Quality and Completeness Criteria
Revision 1 July 18, 2002

Background

Mobile emission source (both engine and vehicle) measurement data collected by testing programs is often used for a variety of purposes, some not anticipated by the original program plan. Often it is critical that certain information about the sources tested or the testing procedures be known in order for the data to be used. For this reason, it is prudent that emission data collection efforts include any incremental observations and measurements that might make the data useful for purposes other than the original intentions of the testing program.

Below are the data observation and measurement fields and testing documentation that EPA OTAQ's Assessment and Standards Division (ASD) considers critical for general use in development of emission inventory modeling. While all fields are not critical for any specific analysis, the total combination of fields allows cross checking of the observation and measurement results, which can be used to identify problems in the data and improve data quality. For this reason, ASD considers the collection of these data fields and the documentation that supports this data critical in determining the quality of the data collected.

Measurements and Observations

Certain measurements and observations should be made during any collection of data for use in emission inventory development. The critical data fields are divided into four groups:

<u>Source Description</u>

- (*)Engine/Vehicle type
- (*)Test weight
- (*)Curb weight (highway only)
- (*)Gross vehicle weight rating (GVWR) (highway only)
- (*)Vehicle identification number (VIN)/engine serial number
- (*) A, B, C Dynamometer Coefficients
- (*)Body style (aero-dynamic issues) (highway only)
- (*)Number of tires (highway only)
- (*)Emission standard (model year, engine family, evap family)
- (*)Age (build date, model year, rebuild)
- (*)Engine size (number of cylinders)
- (*)Transmission type (highway only)
- (*)Mileage/hours of operation

- (*)Fuel type (gas, diesel, CNG, electric, hybrid, etc.)
- (*) Test date
- Fuel delivery technology
- Catalyst technology
- EGR system (yes/no)
- Secondary air system
- Closed loop fuel control (yes/no)
- Aspirated/turbo-charged (yes/no)
- OBD parameters (e.g. A/C flag, RPM, exhaust volume flow, engine coolant temperature, air fuel ratio, etc.)

<u>Pollutants</u> (exhaust only; engine out and/or tailpipe - measured second-by-second, sbs)

- (*)CO2
- (*)CH4
- (*)N2O
- THC/NMHC
- CO
- NOx (NO, NO2)
- SOx
- NH4
- HAPs
- PM10, 2.5, 1.0 (size and number distributions also)

<u>Fuel Parameters</u>

- (*)Diesel sulfur content
- (*)Gasoline sulfur content
- (*)Gasoline Reid Vapor Pressure (RVP)
- (*)Gasoline oxygenate content/type (ETOH,MTBE,ETBE,TAME)
- Gasoline aromatic content
- Gasoline olefin content
- Gasoline Benzene content
- Gasoline vapor percentage at 200 degrees F
- Gasoline vapor percentage at 300 degrees F

<u>Activity</u>

- (*)Speed at time of measurement (highway only)
- (*)Ambient temperature at time of measurement
- Ambient conditions (RSD and PEMS data); ie sunny or overcast, rain, snow, ice, etc
- (*)Soak time before engine start
- Humidity during operation
- Driving/operation cycle/schedule

- Road grade at time of measurement (vertical acceleration) (highway only)
- Air conditioning status at time of measurement (on/off)
- Other high load devices (i.e., large stereo)
- Number of occupants
- Key on (engine start)/key off times
- Barometric pressure/altitude
- Variable load (cargo, passengers, auxiliary systems, road grade, etc.)
- MIL (malfunction illumination light?) (on/off) (highway only)

(*) Indicates high priority parameters for this work assignment.

Ideally, the content and format of each data field will match precisely the content and format of the EPA Mobile Source Observation Database (MSOD) data input format. This would allow these fields to be used to directly populate the MSOD data input format and subsequently added to the MSOD itself for future analysis by EPA. Plans for future data collection efforts should consider adopting the MSOD data input format as a method of storing measurements and observations for ease in providing the data to EPA for analysis. The precise definition and content of each of these data fields is described in the MSOD data input format documentation.

Ideally, each of these fields would be available in every data source from direct observations and measurements. However, it is often possible for some information that could be obtained and recorded by direct observation (i.e., body style) that can instead be derived from other available information (i.e., VIN). This fact allows for the observations and measurements to be checked against each other to determine and improve the quality of the data. This fact can also be used to populate fields that were not directly measured or observed. Fields derived from other fields should not be considered as measurements or observations for purposes of planning future data collection efforts. Whenever possible, direct measurements and observations should be used to fulfill these data completeness criteria.

Documentation

It is not possible to determine the quality of data based solely on the measurement values themselves. The critical test program data documentation is:

- Statement of Work. The objectives of the test plan must be clear. The procedures for selection of engines/vehicles must be described in enough detail to discern the representativeness of the sample.
- Quality Assurance / Quality Control process. The test plan must include procedures that assure proper measurement, proper maintenance of instrumentation and proper handling of data. This should include instrument calibration sheets or other evidence of proper calibration during testing.
- Program reports. The results of testing must be summarized and compared against the goals of the test plan. Running changes in the initial test plan must be described. Problems which occurred during testing must be documented.
- Instrumentation description. The instrumentation used to make measurements must be described in sufficient detail to determine the appropriateness of the tools used.
- Measurement uncertainty. The quality of the instrumentation must be demonstrated. Instrument minimum detection limits must be documented. Reproducibility of data should be demonstrated.

This documentation can be contained in a single document or as a series of documents. The information can be contained in summary reports and tables or exist as forms and sheets produced during testing. In any event, this information must be able to be made available to anyone intending to use the data. Without access to this documentation, the relevance of the data to a specific study cannot be fully determined.

EPA Data Quality and Completeness Criteria

For purposes of evaluation of the quality and completeness of data for use in inventory model development, EPA has developed criteria for documentation and completeness. From this information it will be possible to make a determination of data quality for the purpose of inventory model development.

Documentation Criteria

A) Fully documented :	All desired documentation exists and is available upon request.
B) Can be documented :	All desired documentation can be derived from testing records and charts.
C) Cannot be fully documented :	Some desired documentation is unavailable and necessary information was not recorded.

Completeness Criteria

A) Fully measured :	All critical fields measured and available.

B) Fully complete :	All critical fields are either measured or can be derived from other fields available in the data.
C) Missing data :	Some critical fields were not measured and cannot be derived from other fields available in the data.

The critical list of pollutants will vary from program to program, but the list of source description, fuel and activity parameters are needed to properly characterize and cross check the data.