



COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Attachment C: 2006 Quality Control Report

40 CFR section 51.366(c)

Massachusetts Enhanced Emissions and Safety Test
Inspection and Maintenance Program

August 2007

**Attachment C: 2006 Quality Control Report
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1.0 MassDEP Equipment Audit Procedure

MassDEP developed its equipment audit procedures based on recommendations from its consultant, Sierra Research (Sierra) of Sacramento, CA and audit contractor, SGS TESTCOM, Inc. (TESTCOM) of Ballston Spa, NY. Sierra developed general equipment audit guidelines for EPA for ASM-type equipment used in transient test I&M programs ¹. MassDEP's audit procedures are consistent with EPA's guidance and include many other checks that are unique to the Massachusetts I&M Program. These additional checks are noted in section 4.0.

MassDEP's equipment audit procedure includes the following parts:

Visual Inspection	Visual check that all relevant equipment is connected, powered, and ready to perform an inspection. Check for visual signs of tampering.
Gas Analyzer Visual	Visual check of the gas analyzer including the condition of raw sample system (probe, hose, and filters), on-board calibration gases, and zero air generator.
Weather Station	Accuracy check of the workstation temperature, relative humidity, and barometric pressure readings.
Leak Check	Functional check for leaks in the raw sample system and the analyzer's ability to detect leaks during its 24-hour calibration.
Gas Bench	Accuracy check of the gas bench HC, CO, CO ₂ , NO _x , and O ₂ readings using various audit gas concentrations.
Gas Cap Tester	Functional check of the gas cap tester's ability to distinguish between passing and failing gas caps
RPM pickups	Functional and accuracy check of the inductive and OBDII RPM pickups at 700 and 2,500 RPM.
OBDII Scanner	Visual check of the OBDII cable condition. Functional check of the scanner's ability to communicate with OBDII systems. Accuracy check of the scanner's ability to retrieve specific diagnostic trouble codes (DTCs) and readiness monitor status.
VMAS Visual	Visual check for proper installation of VMAS and condition of hoses.
VMAS O ₂ Sensor	Accuracy check of the VMAS O ₂ sensor using three audit gas concentrations.
VMAS Flow	Accuracy check of VMAS flow measurement at three flow rates.

¹ "U.S. EPA Steady State and Transient Testing Equipment Audit Guidance," July 2001

To focus quality control efforts, in 2004 MassDEP defined “Critical Audit Failures” as malfunctions that may substantially affect test accuracy. Components of these Critical Audit Failures include the gas bench, VMAS, gas cap tester, OBDII tester, and barometric pressure. Critical failures are defined as:

- A critical gas bench audit failure occurs when the bench fails its first bench audit, is re-calibrated and then fails a second bench audit that is conducted immediately after the calibration.
- The critical VMAS failures include failures of either the VMAS flow audit or the 15% dilute O₂ audit.
- The combined critical gas bench/VMAS failure is the result of either a critical gas bench or critical VMAS failure.
- The OBDII Test System critical failure occurs when the OBDII test system fails its audit for communication, readiness codes, or diagnostic trouble codes.
- A gas cap tester critical failure occurs when the gas cap tester fails the first audit, is re-calibrated and then fails a second gas cap tester audit that is conducted immediately after calibration.
- If the barometric pressure has an error of greater than 10%, it is a critical failure.

2.0 MassDEP 2006 Equipment Audit Results

2.1 Number of Stations, Workstations and Equipment Audits

40 CFR 51.366 (c) Quality control report. ...Basic statistics on the quality control program for January through December of the previous year, including:

- (1) The number of emission testing sites and lanes in use in the program;
- (2) The number of equipment audits by station and lane; . . .

In 2006, 1,401 stations and 1,472 workstations (lanes) conducted emissions inspections throughout the year. A total of 1,639 stations and 1,674 workstations conducted emissions tests at some time during the year. This includes workstations and stations that conducted only diesel emissions tests and were therefore not subject to equipment audits.

MassDEP performed a total of 2,065 audits in 2006, which covered 1,282 different workstations (lanes) and 1,271 different inspection stations. 674 workstations were audited one time, 460 workstations were audited two times, 125 workstations were audited three times, 19 workstations were audited four times, and 4 workstations were audited five times. These audits include re-audits at stations that failed items deemed "critical" during initial or follow-up audits. As EPA agreed, Mass DEP randomly selected workstations to receive audits between July 2006 and July 2007. Therefore, not all workstations are scheduled for audits in any given calendar year.

See Section 5 for the results of the 7,057 equipment audits conducted in 2006 by Applus.

2.2 Equipment Audit Results

Table 1 presents a breakdown of the results of audits conducted in 2006, including individual audit parts and overall results. Although a total of 2,065 audits were performed, the number of audit parts tested (table column "Tested") was usually less than 2,065 because not all audits included all audit parts. For some audits, audit parts were excluded because the workstation configuration did not include some parts, such as the VMAS. In the case of re-audits, typically only the parts that failed the initial audit were retested. In other instances, a particular part could not always be audited. For example, if a workstation failed its leak check, even when using a replacement sample hose and probe, the audit of the gas bench could not proceed. When the audit could not be completed for all audit parts, the auditors returned to the station to audit these parts at a later date.

The sum of the failure rates for the individual audit parts is greater than 100%, because a single audit may fail more than one audit part.

Table 1: Equipment Audit Results Summary

Audit Part	2006 Audit Results			
	Pass	Fail	Tested	Failure Rate
Visual Inspection	1,986	79	2,065	3.8%
Gas Analyzer Visual Inspection	1,807	148	1,955	7.6%
Weather Station	1,551	323	1,874	17.2%
Leak Check	1,933	22	1,955	1.1%
1 st Gas Bench Audit	1,825	108	1,933	5.6%
2 nd Gas Bench Audit	17	81	98	82.7%
Gas Cap Tester	1,841	17	1,858	0.9%
Inductive RPM Pickup	1,812	17	1,829	0.9%
OBDII RPM Pickup	1,784	3	1,787	0.2%
OBDII Tester	1,843	0	1,843	0.0%
VMAS Visual Inspection	1,798	40	1,838	2.2%
VMAS Dilute O2 Sensor	1,797	63	1,860	3.4%
VMAS Dilute O2 15% ²	1,855	6	1,861	0.3%
VMAS SAO Flow	1,824	11	1,835	0.6%
Overall Audit Result³	1,435	630	2,065	30.5%
Combined Gas Bench + VMAS⁴	1,861	170	2,031	8.4%
Critical Audit Failures				
Combined Critical Gas Bench/ VMAS	1,936	95	2,031	4.7%
Gas Cap Tester	1,849	9	1,858	0.5%
Barometric Pressure	1,874	0	1,874	0.0%
OBDII Test System	1,843	0	1,843	0.0%

² VMAS Dilute O2 Sensor is a comprehensive result of three audit checks for the accuracy of the VMAS O2 sensor. This check uses three audit gases to determine overall O2 sensor accuracy including 8% O2, 15% O2, and 20.8% O2 (zero air). All three checks must result in “P/F” for VMAS Dilute O2 Sensor to be “tested”. For instance, if an audit check for the 8% O2 is “NA”, but passes the 15% O2 and 20.8% O2, then the VMAS Dilute O2 Sensor is not tested. For this reason it is possible to have more audits of VMAS Dilute O2 15% than there are audits for the overall “VMAS Dilute O2 Sensor.”

³ To pass the overall audit, the workstation cannot fail any individual audit part.

⁴ Combined results from 1st Gas Bench, VMAS Dilute O2, and VMAS Flow audits for each workstation audited.

3.0 Comparison of MassDEP 2006 Results to Prior Years' Results

Table 2 summarizes the results of equipment audits conducted by MassDEP from 2003 through 2006. Of particular interest is the significant improvement from the 2004 13% failure rate for “combined critical gas bench/VMAS audit” items to a 5% failure rate in 2006.

This table also demonstrates that the dramatic improvement in the overall audit failure rate (following the June 2004 program changes) continued in 2006. In 2006, 31% (630 of 2,065) of equipment audits failed one or more of the 88 audit criteria described in Attachment C. This represents continual improvement over the 83% failure rate in 2003, 55% failure rate in 2004 and the 39% failure rate in 2005 .

**Table 2:
MassDEP Equipment Audit Data Summary
2003 through 2006**

Audit Part	2003 Failure Rate	2004 Failure Rate	2005 Failure Rate	2006 Failure Rate
Visual Inspection	7%	6%	4%	4%
Gas Analyzer Visual Inspection	34%	11%	17%	8%
Weather Station	47%	27%	21%	17%
Leak Check	44%	7%	1%	1%
1 st Gas Bench Audit	22%	12%	4%	6%
2 nd Gas Bench Audit ⁵	76%	73%	80%	83%
Gas Cap Tester	17%	7%	2%	<1%
Inductive RPM Pickup	2%	3%	1%	<1%
OBDII RPM Pickup	1%	1%	<1% ⁶	<1%
OBDII Tester	5%	1%	<1%	0%
VMAS Visual Inspection	20%	4%	2%	2%
VMAS Dilute O2 Sensor	31%	27%	8%	3%
VMAS SAO Flow	11%	4%	2%	<1%
Overall Audit Result	83%	55%	39%	31%
Combined Gas Bench and VMAS	38%	32%	12%	8%
Combined Critical Gas Bench/VMAS Audit Items	NA	13%	5%	5%

⁵ Because the 2nd gas bench audit is conducted only after an initial bench audit failure and a successful calibration, a relatively small number of workstations receive a second bench audit (132 in 2003, 99 in 2004, 59 in 2005, and 98 in 2006)

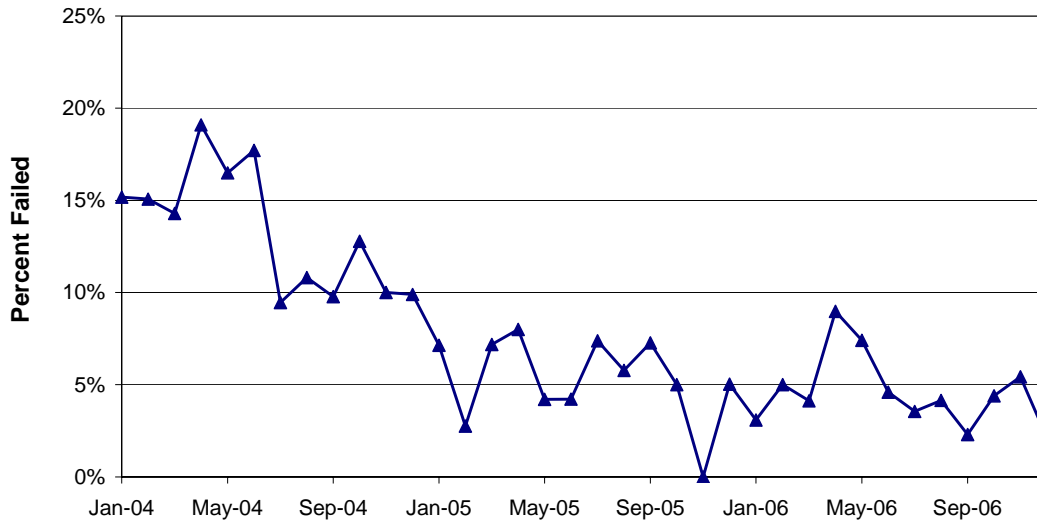
⁶ Beginning in 2005, audit failures less than 1% are indicated as “<1%”.

As can be seen in Table 2, above, the 2006 failure rates for each audit part were either lower or equal to 2005 failure rates for all parts, with the exception of failures for the first gas bench audit and the second gas bench audit, which both increased slightly (2% and 3%, respectively). These minor increases were offset by the significant declines in failure rates of other audit items, which largely result from improved Contractor maintenance of the workstations during the year (through the use of more frequent calibrations and digital audits, and through more frequent auditing).

The minor 2006 increases in gas bench failure rates should be considered in the context of trends in failure rates of all audit items since 2003. First gas bench audit failure rates have declined from a 22% failure rate in 2003 to a 6% failure rate in 2006, and the second gas bench audit failure rates have increased from 76% in 2003 to 83% in 2006. The results of all of the gas bench audits taken together indicate: 1) audits are identifying gas benches that experienced a substantive failure after their last audit, and 2) generally, gas benches no longer have minor problems that are temporarily resolved by a calibration.

Of the workstation components, gas bench and VMAS accuracy have proven to be the most difficult to maintain, and are therefore monitored more closely. The following graph presents the Critical Audit Failure rate for combined gas bench/VMAS failures for 2004, 2005, and 2006. The graph highlights a significant improvement in failure rates for combined critical components during the last half of the 2004, with continued improvements in 2005 and throughout 2006.

Combined Critical Gas Bench/VMAS Audit Failure Rate by Month
- Includes Initial Audits and Re-Audits -



The above graph shows that the 2006 failure rate was highest in April and May. Applus investigated the April failures and identified bench issues that were tied to seasonal changes in humidity. Applus then trained all the repair technicians on newly developed repair strategies and preventive maintenance procedures. The improved failure rates in June 2006 reflect the implementation of the new repair strategies and preventive maintenance procedures.

4.0 MassDEP Audit Details

4.1 Visual Inspection

The visual inspection checks the type of workstation being audited (e.g. whether it is equipped with a dynamometer or has a diesel opacity meter) and includes the following items:

MassDEP Visual Inspection Audit Items	Part of EPA's Audit Guidance?
Signs of tampering	√
Barcode scanner is operational	
Gas cap tester is connected and calibration device NOT attached	√
Dynamometer (if equipped) is connected to workstation and powered	√
Vehicle cooling fan is accessible and functional	
VMAS is connected to workstation and powered	√
Workstation is connected to a dedicated phone line	
Workstation clock shows proper time and date (within 5 minutes)	
Diesel Opacity meter (if equipped) is connected to workstation and powered	

In 2006, 79 of 2,065 workstations audited (3.8%) failed one or more of the visual inspection items.

4.2 Gas Analyzer Visual Inspection

The gas analyzer visual inspection checks the condition of the gas analyzer portion of the workstation and its ancillary equipment and contains the following items:

MassDEP Gas Analyzer Visual Inspection Audit Items	Part of EPA's Audit Guidance?
There are no non-stock components in the sample system hose assembly	None
Auxiliary sample hose and probe are available for testing dual exhaust vehicles	
Inlet filter housing and elements are present and appear functional	
On-board calibration gas cylinders have an official BAR-97 label and bar code	
Calibration gas cylinder concentrations match those stored on the analyzer	
Workstation is equipped with a zero air generator (ZAG)	
ZAG is connected to workstation and powered	
ZAG inlet filter and filter element are present	

In 2006, 148 of 1,955 workstation audits (7.6%) failed one or more of the gas analyzer visual inspection items.

4.3 Weather Station Audit

The weather station audit checks the accuracy of the workstation's weather station against a NIST-traceable calibrated portable audit weather station. Starting on July 1, 2006, the weather station audit tolerance for temperature was changed from ± 4.0 deg F, (absolute), to ± 4.5 deg F (absolute). This change was made to prevent false failures caused by the auditors' weather stations being inadvertently set so that they did not read to one decimal place.

The weather station audit contains the following items and specifications:

MassDEP Weather Station Audit Items	MassDEP Pass/Fail Tolerance		Part of EPA's Audit Guidance?
	January - June 2006	July - December 2006	
Barometric Pressure, in Hg	$\pm 3\%$ of reading and ± 0.1 in Hg absolute	$\pm 3\%$ of reading and ± 0.1 in Hg absolute	√
Temperature, deg F	± 4 deg F, absolute	± 4.5 deg F, absolute	√
Relative Humidity, %	$\pm 8.5\%$ absolute	$\pm 8.5\%$ absolute	√

In 2006, 323 of 1,874 workstation audits (17.2%) failed one or more of the weather station audit items. If the barometric pressure has an error of greater than 10%, it is considered a Critical Audit Failure. In 2006, there were no Critical Audit Failures for barometric pressure.

4.4 Leak Check

The workstation requires the inspector to perform a leak check of its raw exhaust sample system as part of its 24-hour calibration procedure. This sample system consists of external components such as a probe tip (that is inserted into the tailpipe), probe tip handle (that the sample flows through), rubber hose, particle filter, and internal components such as the sample pump, solenoid valves, and assorted plumbing leading up to the gas bench. It is the station's responsibility to maintain the external sample system components so that they do not have any leaks.

The MassDEP leak check audit contains two checks for determining the condition of the raw exhaust sample system and verifying the ability of the MASS99 system to self-detect leaks:

MassDEP Leak Check Audit Items	Part of EPA's Audit Guidance?
Leak check fails with probe uncapped	√
Leak check passes with probe capped	√

If the workstation cannot pass its leak check with the probe capped, the auditor attempts to make repairs to obvious problems with the sample system (such as tightening a loose fitting) and repeats the check. If the workstation cannot pass its leak check with the probe capped, the auditor replaces the probe tip, handle, and/or hose as needed to fix the problem and repeats the check. If the workstation does not fail the leak check with the probe uncapped or pass the leak check with the probe capped following repairs or parts replacement, a gas bench audit is not performed. In these cases, the results are reported immediately to MassDEP personnel and a priority service visit is arranged for the workstation. When repairs have been confirmed, the auditors return to the station to complete an audit of any skipped audit parts.

In 2006, 22 of 1,955 workstation audits (1.1%) failed either the leak check capped or uncapped test, equaling the notable improvement observed in 2005 (1.1%), and extending the improvement over the 6.7% failure rate reported in 2004, and the failure rate of 47% reported in 2003. This improvement is the result of two factors: implementing an aggressive inspection and maintenance program to track leak-check related components and, in July 2004, switching the type of probe tip used, from a flexible probe to a more rigid “needle” type probe.

4.5 Raw Transport Time Check

In 2006, the raw transport time check was not performed. Prior to 2005, only one of the equipment vendors, ESP, required a raw transport time check to be performed as part of the 72-hour calibration routine performed by the inspector. The other vendor, SPX, automatically determines the raw transport time for its sample system that cannot be changed by the inspector. Due to the replacement of all ESP workstations (which Applus reported to be complete by February 28, 2005), no raw transport time audits were conducted after 2004.

4.6 Gas Bench Audit

The gas bench audit uses 6 different audit gas blends to check the ability of the workstation to accurately measure the range of hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), oxides of nitrogen (NO_x), and oxygen (O₂) that may be present during an emissions test. The gas bench audit has the following specifications:

Audit Gas Blend	Component	Target Concentration	MassDEP audit tolerance- 1 st gas bench audit ⁷	MassDEP audit tolerance- 2 nd gas bench audit	Part of EPA's Audit Guidance?
Zero Air	HC, ppm	0	± 9 ppm absolute	± 9 ppm absolute	√
	CO, %	0	± 0.04% absolute	± 0.02% absolute	√
	CO ₂ , %	0	± 0.6% absolute	± 0.3% absolute	√
	NO, ppm	0	± 26 ppm absolute	± 26 ppm absolute	√
	O ₂ , %	20.9	± 10% of bottle	± 6% of bottle	√
1% oxygen	O ₂ , %	1.0%	± 0.2% absolute	± 0.1% absolute and ± 1% of bottle	√
BAR-97 Low	HC, ppm	200	± 6% of bottle	± 8 ppm absolute and ± 1% of bottle	√
	CO, %	0.50%	± 6% of bottle	± 0.02% absolute and ± 1% of bottle	√
	CO ₂ , %	6.0%	± 0.36% absolute	± 0.3% absolute and ± 1% of bottle	√
	NO, ppm	300	± 28 ppm absolute	±25 ppm absolute and ± 1% of bottle	√
BAR-97 Mid 1	HC, ppm	960	± 6% of bottle	± 4% of bottle	√
	CO, %	2.4%	± 6% of bottle	± 4% of bottle	√
	CO ₂ , %	3.6%	± 0.34% absolute	± 0.3% abs and ± 1% of bottle	√
	NO, ppm	900	± 8% of bottle	± 5% of bottle	√
BAR-97 Mid 2	HC, ppm	1920	± 6% of bottle	± 4% of bottle	√
	CO, %	4.8%	± 6% of bottle	± 4% of bottle	√
	CO ₂ , %	7.2%	± 6% of bottle	± 0.3% abs and ± 1% of bottle	√
	NO, ppm	1800	± 8% of bottle	± 5% of bottle	√
BAR-97 High	HC, ppm	3200	± 6% of bottle	± 4% of bottle	√
	CO, %	8.0%	± 6% of bottle	± 4% of bottle	√
	CO ₂ , %	12.0%	± 6% of bottle	± 4% of bottle	√
	NO, ppm	3000	± 8% of bottle	± 5% of bottle	√

⁷ “Of bottle” for the audit tolerance indicates a percentage of the relevant audit gas bottle concentration.

If the workstation fails to read any one of the audit gases within the specified tolerances in the first gas bench audit, the auditor calibrates the workstation and conducts the gas bench audit a second time.

In 2006, 108 of 1,933 workstation audits (5.6%) failed to read one or more of the audit gases within the specified tolerances during the first gas bench audit. This is a slight increase in failure rate from 2005 (3.8%), yet still a significant improvement from 2004 when 11.7% failed one or more of the gases during the first gas bench audit. In 2003, 21.5% failed the first bench audit. This slight increase between 2005 and 2006 first gas bench audit failure rates is within the bounds of reasonable year-to-year variation.

In 2006, 81 of 98 workstation audits (82.7%) failed the first gas bench audit and then failed the second gas bench audit following calibration⁸. These failures constitute 85% of all critical combined gas bench and VMAS audit failures in 2006 (there were 95 in total), and 4% of all critical combined gas bench and VMAS audits (there were 2,031 in total).

While 2006 failure rates for second gas bench audits appear to be high, please consider that the number of gas benches that failed their first audit and were recalibrated⁹ has decreased significantly since 2003 so that the small number of failed second gas bench audits is a large percentage of the number of first gas bench audit failures. In addition, the high percentage of second gas bench audit failures indicates that these audits are successfully identifying gas benches that experienced a substantive failure after their last audit, and also indicates that the contractor’s improved maintenance generally takes care of small problems before they become audit failures, so that these audits are no longer identifying gas benches that have minor problems that are temporarily resolved by a calibration.

4.7 Gas Cap Tester

The gas cap tester audit consists of checks that the station has all of the necessary gas cap adapters and a gas cap calibration device, and checks the workstation’s ability to distinguish between passing and failing gas caps. The gas cap tester audit contains the following items:

MassDEP Gas Cap Tester Audit Items	Part of EPA’s Audit Guidance?
All gas cap adapters are available	√
Calibration device/caps are available	√
Audit “Pass” cap passes test	√
Audit “Fail” cap fails test	√

⁸ Since the Workstations are calibrated frequently during normal operation, the majority of Workstations that failed the first bench audit also fail the second bench audit that is conducted after a calibration. The 81 audits that failed the second bench audits are 4.2% of all bench audits and 82.7% of the second bench audits.

⁹ Some workstations could not pass the gas bench calibration after failing the first gas bench audit and were automatically locked out from further testing. These workstations did not receive a second gas bench audit.

MassDEP uses two audit gas caps (one set to pass, the other set to fail) to audit the gas cap tester. If the workstation does not produce the correct result for either of the audit gas caps, then it fails the gas cap tester audit and the audit is repeated. If the audit fails either of the gas cap retests, then the audit is repeated using the station's calibration device. These additional steps allow the gas cap audit to verify the initial results and determine if the station's calibration device was faulty.

In 2006, 17 of 1,858 workstation audits (0.9%) failed one or more of the items in the gas cap tester audit. This was a slight improvement over 2005 (1.8%). The 2005 and 2006 improvement over the 6.5% failure rate for 2004 is mainly due to replacing the gas cap testing equipment that was provided by one of the equipment vendors. There were 9 critical gas cap tester failures in 2006 (0.5% critical failure rate for gas cap audits). 52.9% of the gas cap tester failures were critical failures.

4.8 Inductive RPM Pickup

MassDEP uses an RPM signal generator to check the accuracy of the inductive RPM pickup, that clamps around the sparkplug wire, at 700 and 2,500 RPM. The inductive RPM pickup audit contains the following items:

MassDEP Inductive RPM pickup Audit Items	MassDEP Pass/Fail Tolerance	Part of EPA's Audit Guidance?
RPM pickup is in good condition and connected to the workstation		
Low Idle @ 700 RPM	± 3.3% of reading	√
High Idle @ 2,500 RPM	± 3.3% of reading	√

In 2006, 17 of 1,829 workstation audits (0.9%) failed one or more of the items in the inductive RPM pickup audit.

4.9 OBDII RPM Audit

The Massachusetts I&M Program uses the OBDII tester to record RPM from 1996 and newer OBDII equipped vehicles if they receive a Two-Speed-Idle test. MassDEP uses an OBDII simulator to generate a data stream to check the accuracy of the OBDII scanner at 700 and 2,500 RPM. The OBDII RPM audit contains the following items:

MassDEP OBDII RPM Audit Items	MassDEP Pass/Fail Tolerance	Part of EPA's Audit Guidance?
OBDII cable and connector are in good condition and connected to the workstation		
Low Idle @ 700 RPM	± 10% of reading	√
High Idle @ 2,500 RPM	± 10% of reading	√

In 2006, 3 of 1,787 workstation audits (0.2%) failed one or more of the items in the OBDII RPM audit. All three OBDII failures (RPM and tester audits combined) were due to poor conditions of cable box connections and were not due to inaccuracies.

4.10 OBDII Tester Audit

The OBDII Tester audit contains: 1) a check that the OBDII tester can communicate with a vehicle's OBDII system and 2) an accuracy check to verify that the OBDII tester correctly reads the malfunction indicator light (MIL) status, diagnostic trouble codes (DTCs), and the status of all readiness monitors. MassDEP uses an OBDII simulator to generate signals for MIL status, DTCs and readiness monitor status that simulate the output of a vehicle's OBDII system. The OBDII tester audit consists of the following items:

MassDEP OBDII Tester Audit Items	Part of EPA's Audit Guidance?
Workstation communicates with OBDII simulator	√
MIL status	√
Misfire monitor status	√
Fuel System monitor status	√
Component monitor status	√
Catalyst monitor status	√
Heated Catalyst monitor status	√
Evaporative System monitor status	√
Secondary Air monitor status	√
A/C System monitor status	√
O2 Sensor monitor status	√
O2 Sensor Heater monitor status	√
EGR monitor status	√
DTC 1	√
DTC 2	√
DTC 3	√
DTC 4	√
DTC 5	√
DTC 6	√

In 2006, none of 1,843 workstation audits (0.0%) failed one or more of the items in the OBDII Tester audit. There was a 0.0% critical failure rate for the OBDII test system.

4.11 VMAS Visual Inspection

The VMAS visual inspection checks the condition of the VMAS and its ancillary equipment and contains the following items:

MassDEP VMAS Visual Inspection Audit Items	Part of EPA's Audit Guidance?
VMAS blower is mounted correctly	None
Damage (cracks, leaks, loose fit) of the blower or VMAS tube	
Vortex strut missing or severely damaged	
Thermistor bent or severely damaged	
VMAS inlet hose is free from tears or leaks	
VMAS inlet hose has an exhaust cone attached	
VMAS inlet hose is between 5 and 20 feet long	
Auxiliary hose, cone, and clamps are available for testing dual-exhaust vehicles	
VMAS LEDs are blinking alternately each second (indicating no faults)	

In 2006, 40 of 1,838 workstation audits (2.2%) failed one or more of the VMAS visual inspection items.

4.12 VMAS Dilute O2 Sensor

The VMAS dilute O2 sensor audit checks the accuracy of the VMAS O2 sensor using three audit gases: 8% O2, 15% O2, and 20.8% O2 (zero air) and has the following specifications:

MassDEP VMAS Dilute O2 Sensor Audit Items	MassDEP Pass/Fail Tolerance	Part of EPA's Audit Guidance?
8% O2 audit gas	± 5% of bottle and ± 3% of absolute	√
15% O2 audit gas	± 5% of bottle and ± 3% of absolute	√
20.8% O2 (zero air) audit gas	± 5% of bottle and ± 3% of absolute	

In 2006, 63 of 1,860 workstation audits (3.4%) failed one or more of the VMAS dilute O2 sensor audit gases. However, only 6 of the 1,861 workstation audits for the 15% O2 audit gas (0.3%) failed this audit check, and were therefore Critical Audit Failures. These critical failures constituted 6.3% of the 95 critical combined bench and VMAS failures.

4.13 VMAS Flow

The VMAS flow audit checks the accuracy of the VMAS flow sensor at three points: minimum flow (~225 standard cubic feet per minute, or scfm), maximum flow (usually 400 to 450 scfm), and a mid-point in between. MassDEP uses a smooth approach orifice (SAO) as a flow standard that is compared with the VMAS flow measurement indicated by the workstation. The VMAS flow audit has the following specifications:

MassDEP VMAS Flow Audit Items	MassDEP Pass/Fail Tolerance	Part of EPA's Audit Guidance?
Maximum Flow (~ 400 to 450 scfm)	± 10% of reading	√
Mid Flow	± 10% of reading	√
Minimum Flow (~ 225 scfm)	± 10% of reading	√

In 2006, 11 of 1,835 workstation audits (0.6%) failed one or more of the VMAS flow points. This is an improvement over both 2005 (1.9%) and 2004 (3.7%) and it is a significant improvement over the 11.2% failure rate in 2003. These 11 VMAS flow audit failures also constituted critical combined bench and VMAS audit criteria and were 12% of all critical combined bench and VMAS audit failures (there were 95 in total), and were 0.5% of all critical combined bench and VMAS audits (there were 2,031 in total).

4.14 Functional Dynamometer Check

The workstation requires a dynamometer coast-down check to be performed as part of its 72-hour calibration procedure. If the coast-down check fails, the workstation automatically performs a test to determine the parasitic losses in the dynamometer roll system. If these parasitic losses are within manufacturer's specifications, then a second coast-down check is performed using the new parasitic loss values. If the parasitic loss values are not within manufacturer's specifications or the dynamometer fails its second coast-down check, then the dynamometer fails its calibration and the workstation is automatically locked out from testing. Because the MASS99 system has this extensive automated coast-down check and lockout mechanism, MassDEP's audit procedure does not specifically include performing a coast-down check for the workstation dynamometer.

4.15 Stations Shut Down as a Result of Equipment Audits

40 CFR 51.366 (c) Quality control report. ...Basic statistics on the quality control program for January through December of the previous year, including:

(4) Number and percentage of stations and lanes shut down as a result of equipment audits.

Workstations were immediately shut down and suspended from performing inspections until repairs could be made on 24 occasions in 2006 as a result of equipment audits. This constituted 1.2% of

the 2,065 audits. These 24 shutdowns occurred at 24 different stations, affecting 24 different workstations. This represents 1.9% of the 1,271 audited stations and 1.9% of the 1,282 audited workstations¹⁰. This was equivalent to 1.4% of all 1,674 stations and 1.5% of all 1,639 workstations that conducted emissions tests sometime during 2006.

Eleven workstations were shut down because they failed more than one audit part: nine workstations were shut down because of problems with the gas bench, one workstation was shut down because of the gas cap tester and OBD II system, and one workstation was shut down because of the gas bench and VMAS. There were five workstations that were shut down due to serious gas bench issues that prevented a calibration after the first bench audit failure (and prevented the subsequent second bench audit).

4.16 Investigation of Audit Anomalies

As part of ongoing quality control of the equipment audits, MassDEP and Applus review the equipment audit results. Anomalous results lead to further investigation that may include a side-by-side testing with multiple Applus and MassDEP auditors and multiple sets of audit equipment. In 2006, investigations resulted in modification of the audit results for 7 MassDEP overt audit failures, as shown in Table 3.

Table 3: Modifications of Audit Results Due to Audit Anomalies

#	Failure Type	Reason for Modification	Modification of Audit Data
1	OBDII	Typographical error	Changed from "F" to "NA" ¹¹ for the result indicating a worn OBD cable and connector.
1	VMAS Flow	Defective audit equipment (Mercial)	Flow audit was changed from "F" to "NA"
1	VMAS Flow	Workstation was re-audited before repairs were completed. Repairs were delayed while MassDEP and Applus investigated the prior failure.	Flow audit was changed from "F" to "NA"
2	Bench	First calibration of the bench was not conducted at the correct time, during the audits, for workstations where the gas bottle values entered in the workstation did not match the labeled gas bottle values.	Bench audits were changed from "F" to "NA"

¹⁰ The number of workstations shut down during an audit includes audits where the auditor recorded "yes" for "workstation lockout." The 24 workstation lockouts may under-count the number of workstations that were prevented from completing further inspections. Workstation benches which did not pass a second gas bench recalibration attempt were most likely to have been locked out due to the failure to calibrate. There were a total of 196 audits that failed the first gas bench and yet did not receive the second gas bench audit.

¹¹ "NA" means "not applicable".

#	Failure Type	Reason for Modification	Modification of Audit Data
2	VMAS Dilute O ₂	Out-of-tolerance zero air audit gas was used to calibrate the VMAS O ₂ sensors during the audits.	The 8% Dilute O ₂ Sensor audit results were changed from "F" to "NA" for both of these audits, and one audit's 15% Dilute O ₂ result was changed from "F" to "NA". The overall VMAS Dilute O ₂ Sensor results were changed to "NA."

4.17 Overall Audit Results

Overall in 2006, 630 of the 2,065 workstation audits (30.5%) failed one or more of the 88 audit items described in previous sections. This represents a continuous improvement over the 82.5% failure rate for 2003, the 54.9% failure rate for 2004, and the 39.2% failure rate for 2005. Also in 2006, 170 of 2,031 workstation audits (8.4%) failed the first gas bench audit, VMAS Dilute O₂ sensor, or VMAS SAO Flow audits. This was an improvement over the 31.5% failure rate in 2004 and the 11.9% failure rate for 2005.

For combined critical gas bench/ VMAS audit items, 95 of 2,031 workstation audits (4.7%) failed at least one of the critical bench or VMAS audit items. This was an improvement over the 13.3% failure rate for 2004 and the 5.4% failure rate for 2005 for the critical bench or VMAS audit items.

4.18 Overall Audit Results by Station

40 CFR 51.366 (c) Quality control report. ...Basic statistics on the quality control program for January through December of the previous year, including: . . .

(3) The number and percentage of stations that have failed equipment audits; . . .

Of the 2,065 equipment audits conducted, 630 failed one or more audit parts, which was a 30.5% failure rate. In total, 542 different inspection stations failed at least one MassDEP audit criteria on at least one audit. This was 42.6% of the 1,271 stations audited in 2006.

5.0 Applus Equipment Audit Results

Applus developed its equipment audit procedures based on the procedures implemented by MassDEP and its audit contractor, TESTCOM. These audits are part of Applus' maintenance program, and one part of their effort to identify and repair underperforming workstations.

Applus' equipment audit procedure includes the following parts:

Visual Inspection	Visual check that all relevant equipment is connected, powered, and ready to perform an inspection. Check for visual signs of tampering.
Gas Analyzer Visual	Visual check of the gas analyzer including the condition of raw sample system (probe, hose, and filters), on-board calibration gases, and zero air gas generator.
Leak Check	Functional check for leaks in the raw sample system and the analyzer's ability to detect leaks during its 24-hour calibration.
Gas Bench	Accuracy check of the gas bench HC, CO, CO ₂ , NO _x , and O ₂ readings using 6 different audit gases.
Gas Cap Tester	Functional check of the workstation's ability to distinguish between passing and failing gas caps.
VMAS Visual	Visual check for proper installation of VMAS and condition of hoses.
VMAS O ₂ Sensor	Accuracy check of the VMAS O ₂ sensor using two audit gases and ambient air.
VMAS Flow	Accuracy check of VMAS flow measurement at three flow rates.

Applus performed a total of 7,057 audits in 2006. 1,532 different workstations (lanes) were audited. 6 workstations were audited once, 3 workstations were audited twice, 14 workstations were audited three times, 790 workstations were audited four times, 525 workstations were audited five times, 157 workstations were audited six times, 26 workstations were audited seven times, 6 workstations were audited eight times, four workstations were audited nine times, and one workstation was audited 10 times.

There were a few areas where MassDEP and Applus equipment audit procedures differed. In one instance, the MassDEP gas cap test is based on two criteria:

- Visual: it is connected to the workstation and the calibration device is not attached (and all 8 gas cap adapters and the calibration wand are available)
- Performance: the device passes the pass cap, and the device fails the fail cap.

A gas cap tester may fail a MassDEP audit for either of these criteria. Applus' audit procedure for the gas cap tester combines the visual and performance criteria into a single pass/fail result.

The MassDEP and Applus audits also differ in how they treat failed workstation components. Components that fail an Applus audit are typically repaired or replaced during the audit. In Table 4, MassDEP counts any components that were repaired during the Applus audit as failures, reflecting

the condition of the equipment as found, rather than as following repairs performed during the audit. No repairs are performed during MassDEP audits.

Table 4 presents a breakdown of results for the individual audit parts and the overall audit result. Although a total of 7,057 Applus audits were performed, the number of audit parts tested (table column “Tested”) was somewhat less than this because not all audits were complete audits.

Table 4: Equipment Audit Results 2006

Audit Part	Applus Technologies				MassDEP ¹²
	Pass	Fail	Tested	Failure Rate	Failure Rate
Visual Inspection	6,939	75	7,014	1.1%	3.8%
Gas Analyzer Visual Inspection	6,177	855	7,032	12.2%	7.6%
Weather Station	NA				17.2%
Leak Check	6,831	224	7,055	3.2%	1.1%
1 st Gas Bench Audit	5,621	396	6,017	6.6%	5.6%
2 nd Gas Bench Audit	NA				82.7%
Gas Cap Tester	7,038	17	7,055	0.2%	0.9%
Inductive RPM Pickup	NA				0.9%
OBDII RPM Pickup	NA				0.2%
OBDII Tester	NA				0.0%
VMAS Visual Inspection	6,802	187	6,989	2.7%	2.2%
VMAS Dilute O2 Sensor	5,689	176	5,865	3.0%	3.4%
VMAS Dilute O2- 15%	5,820	46	5,866	0.8%	0.3%
VMAS Dilute O2- 8%	5,690	176	5,866	3.0%	3.4%
VMAS SAO Flow	4,338	198	4,536	4.4%	0.6%
Overall Audit Result	5,348	1,709	7,057	24.2%	30.5%
Combined Gas Bench + VMAS	6,181	737	6,918	10.7%	8.4%
Critical Audit Failures					4.7%
Combined Critical Gas Bench/ VMAS	NA				
Gas Cap Tester	NA				0.5%
Barometric Pressure	NA				0.0%
OBDII Test System	NA				0.0%

Table 5 compares the failure rates for Applus equipment audits in 2005 and 2006. Note that the failure rate does not necessarily reflect the expected failure rate for the network as a whole because Applus sometimes conducts multiple audits of failing workstations, until an audit confirms that repairs were successful.

¹² See Table 1 in Section 2.2 for the number of MassDEP audits performed and the number of audit failures for each audit part.

Table 5: Applus Technologies Equipment Audit Results for 2005 and 2006

Audit Part	2005 Failure Rate	2006 Failure Rate
Visual Inspection	0.5%	1.1%
Gas Analyzer Visual Inspection	18.0%	12.2%
Leak Check	1.6%	3.2%
1 st Gas Bench Audit	4.6%	6.6%
Gas Cap Tester	0.3%	0.2%
VMAS Visual Inspection	2.3%	2.7%
VMAS Dilute O2 Sensor	3.3%	3.0%
VMAS Dilute O2- 15%	1.1%	0.8%
VMAS Dilute O2- 8%	3.3%	3.0%
VMAS SAO Flow	3.6%	4.4%
Overall Audit Result	25.8%	24.2%
Combined Gas Bench + VMAS	8.1%	10.7%