



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

Attachment C: 2005 Quality Control Report

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Massachusetts Enhanced Emissions and Safety Test
Inspection and Maintenance Program

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1.0 MassDEP Equipment Audit Procedure

MassDEP developed its equipment audit procedures based on recommendations from its consultant, Sierra Research of Sacramento, CA (Sierra) 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 procedure mirrors EPA's guidance document and includes many other checks that are unique to the Massachusetts I&M Program. These additional checks are noted in section 2.0.

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 gas 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 6 different audit gases.
Gas Cap Tester	Functional check of the workstation'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 O2 Sensor	Accuracy check of the VMAS O ₂ sensor using three audit gases.
VMAS Flow	Accuracy check of VMAS flow measurement at three flow rates.

In order 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 were defined as the gas bench, VMAS, gas cap tester, OBDII tester, and barometric pressure.²

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

² A Critical gas bench audit failure is when the bench fails its first bench audit, is re-calibrated and then fails its second bench audit, immediately after the calibration. Critical VMAS failures include failures of

2.0 MassDEP 2005 Equipment Audit Results

MassDEP performed a total of 1,931 audits in 2005. 1,216 different workstations (lanes) and 1,215 different inspection stations were audited. 447 workstations were audited two times, 97 workstations were audited three times, 17 workstations were audited 4 times, 3 workstations were audited 5 times, 1 workstation was audited 6 times, and 1 workstation was audited 7 times. These audits include re-audits at stations failing items deemed critical during initial or follow-up audits. As EPA agreed, Mass DEP randomly selected workstations to receive audits between July 2005 and July 2006. Therefore, not all Workstations were audited in 2005. See Section 5 of the main report for a description of Applus's equipment audits in 2005.

Table 1 presents a breakdown of the results of audits conducted in 2005, including individual audit parts and overall results. Although a total of 1,931 audits were performed, the number of audit parts tested (table column "Tested") was somewhat less than this because not all audits were complete audits. 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 due to circumstances that are described in the sections below. Also, the sum of the failure rates for the individual audit parts is greater than 100%. This occurs because a single audit may fail more than one audit part.

the VMAS flow audit or 15% dilute O₂ audit. The Combined Critical Gas Bench/VMAS failure is when the workstation has either a Critical Gas Bench or Critical VMAS failure. If the barometric pressure has an error of greater than 10%, it is considered a Critical Audit Failure.

Table 1: Equipment Audit Results Summary

Audit Part	2005 Audit Results			
	Pass	Fail	Tested	Failure Rate
Visual Inspection	1,847	84	1,931	4.4%
Gas Analyzer Visual Inspection	1,470	303	1,773	17.1%
Weather Station	1,018	272	1,290	21.1%
Leak Check	1,744	21	1,765	1.2%
1 st Gas Bench Audit	1,673	66	1,739	3.8%
2 nd Gas Bench Audit	12	47	59	79.7%
Gas Cap Tester	1,682	31	1,713	1.8%
Inductive RPM Pickup	1,671	22	1,693	1.3%
OBDII RPM Pickup	1,641	5	1,646	0.3%
OBDII Tester	1,682	7	1,689	0.4%
VMAS Visual Inspection	1,673	38	1,711	2.2%
VMAS Dilute O2 Sensor	1,617	141	1,758	8.0%
VMAS Dilute O2- 15% ³	1,730	28	1,758	1.6%
VMAS SAO Flow	1,679	32	1,711	1.9%
Overall Audit Result⁴	1,175	756	1,931	39.2%
Combined (Gas Bench + VMAS)⁵	1,670	225	1,895	11.9%
Critical Audit Failures				
Combined Critical Gas Bench/ VMAS ⁶	1,792	103	1,895	5.4%
Gas Cap Tester	1,692	21	1,713	1.2%
Barometric Pressure ⁷	1,290	0	1,290	0.0%
OBDII Test System	1,682	7	1,682	0.0%

³ VMAS Dilute O2- 15% is a subset of the audit of the 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). Only failures for the 15% O2 audit gas are deemed a Critical Audit Failure.

⁴ To pass the overall audit, the workstation cannot fail any individual audit part.

⁵ Combined results from 1st Gas Bench, VMAS Dilute O2, and VMAS Flow audits for each workstation audited.

⁶ A Critical gas bench audit failure occurs when a bench fails its first bench audit, is re-calibrated and then fails a second bench audit, immediately after the calibration. Critical VMAS failure occurs when the VMAS fails the flow audit or 15% dilute O2 audit. The Combined Critical Gas Bench/VMAS failure occurs when the workstation has a Critical Gas Bench or VMAS failure.

⁷ Barometric pressure must have an error of greater than 10% in order to be considered a critical audit failure.

3.0 Comparison of MassDEP 2005 Results to 2003 and 2004 Results

Table 2 summarizes the results of equipment audits from 2003-2005. 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 2005. This table also demonstrates a dramatic improvement in the overall audit failure rate, due to the June 2004 program changes. In 2005, 39% (756 of 1,931) of equipment audits failed one or more of the 88 audit criteria described in Attachment C. This represents continual improvement over the 55% failure rate in 2004 and the 83% failure rate in 2003.

Table 2:
MassDEP Equipment Audit Data Summary
2003, 2004, and 2005

Audit Part	2003 Failure Rate	2004 Failure Rate	2005 Failure Rate
Visual Inspection	7%	6%	4%
Gas Analyzer Visual Inspection	34%	11%	17%
Weather Station	47%	27%	21%
Leak Check	44%	7%	1%
1 st Gas Bench Audit	22%	12%	4%
2 nd Gas Bench Audit ⁸	76%	73%	80%
Gas Cap Tester	17%	7%	2%
Inductive RPM Pickup	2%	3%	1%
OBDII RPM Pickup	1%	1%	<1% ⁹
OBDII Tester	5%	1%	<1%
VMAS Visual Inspection	20%	4%	2%
VMAS Dilute O2 Sensor	31%	27%	8%
VMAS SAO Flow	11%	4%	2%
Overall Audit Result ¹⁰	83%	55%	39%
Combined Gas Bench and VMAS ¹¹	38%	32%	12%
Combined Critical Gas Bench/VMAS Audit Items ¹²	NA	13%	5%

⁸ 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, and 59 in 2005).

⁹ Beginning in 2005, audit failures less than 1% are indicated as “<1%”.

¹⁰ To pass the overall audit, the workstation cannot fail any individual audit part.

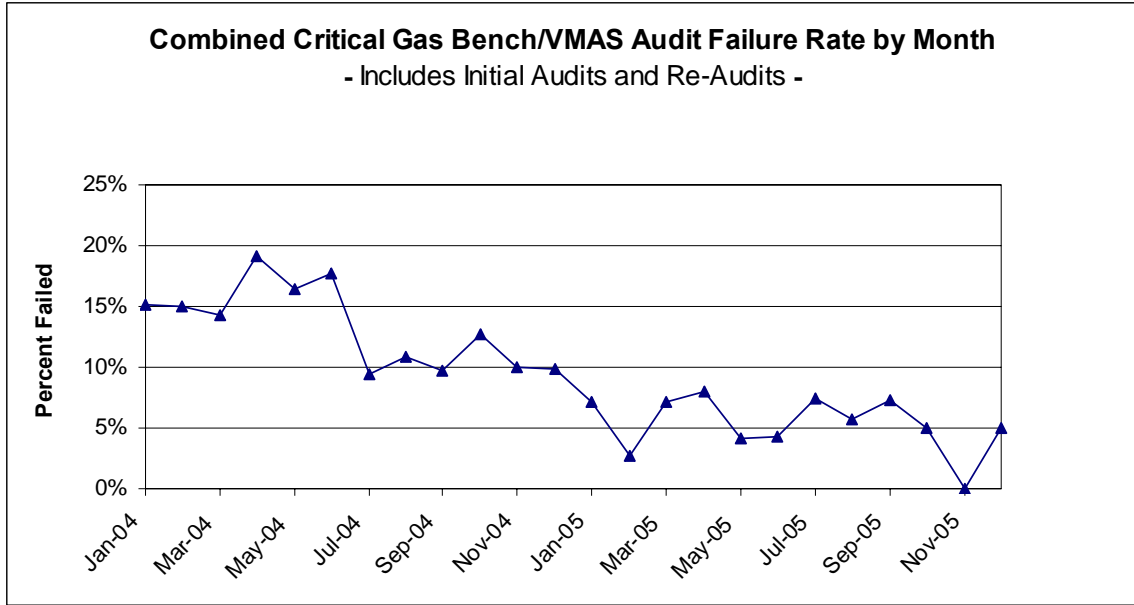
¹¹ Combined results from first gas bench, VMAS dilute O2, and VMAS flow audits for each workstation audited.

As can be seen in Table 2 above, the failure rates for each audit part were lower in 2005 than in 2004 for all parts with two exceptions:

- *Gas analyzer visual inspection.* The most significant new source of failures in 2005 was due to a rounding issue with gas values on bottle labels that had been redesigned without revising the scanning software used to read the values. Revised labels for low-gas gas bottles used to calibrate CO₂ did not match the bar-code scanned values that were stored in the Workstations because they rounded to a different number of decimals. For example, if the CO₂ value on the bottle label read 5.98, the scanned value in the workstation was 6.0. During 2005, this inconsistency constituted a failure for the gas analyzer visual inspection, even though the bottle values were actually consistent with the bottle values stored in the workstation. In mid-2006, the audit procures were revised so that this issue no longer constituted an audit failure.
- *Second gas bench audit.* This audit is conducted only after an initial bench audit failure and a successful calibration. Though the percentage of second bench failures increased from 2004 to 2005, the total number of failures decreased from 99 failures in 2004 to 59 in 2005. Similarly, the second bench audit failures, as a percent of all bench audits, decreased from 7% in 2004 to 3% in 2005.

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 and 2005. 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.

¹² A Critical Gas Bench audit failure occurs when a bench fails its first bench audit, is re-calibrated, and then fails a second bench audit immediately after the calibration. Critical VMAS failure occurs when the VMAS fails the flow audit or 15% dilute O₂ audit. The Combined Critical Gas Bench/VMAS failure occurs when the workstation has a Critical Gas Bench or VMAS failure.



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 2005, 84 of 1,931 workstations audited (4.4%) 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 2005, 303 of 1,773 workstations audited (17.1%) 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. Two revisions were made to weather station audit tolerances, starting June 1, 2005:

1. barometric pressure tolerance was changed to reflect the correct audit equipment accuracy, and
2. humidity tolerance was changed to reflect the correct audit equipment accuracy and to reflect that the MASS99 equipment accuracy for humidity is 3% absolute, rather than 3% "of full range."

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 - May 2005	June - December 2005	
Barometric Pressure, in Hg	± 3% of reading and ± 0.004 in Hg absolute	± 3% of reading and ± 0.1 in Hg absolute	√
Temperature, deg F	± 4 deg F, absolute	± 4 deg F, absolute	√
Relative Humidity, %	± 5% of reading and ± 3% absolute	±8.5 % absolute	√

In 2005, 272 of 1,290 workstations audited (21.1%) 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 2005, 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.

In 2005, 21 of 1,765 workstations audited (1.2%) failed either the leak check capped or uncapped test, a notable improvement over the failure rate of 47% reported in 2003, and over the 6.7% failure rate reported in 2004. 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 2005, the raw transport time check was no longer performed. In prior years, 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 in 2005.

4.6 Gas Bench Audit

The gas bench audit uses 6 different gases 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 ¹³	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	√

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 2005, 66 of 1,739 workstations audited (3.8%) failed to read one or more of the audit gases within the specified tolerances during the first gas bench audit. This is 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.

¹³ “Of bottle” for the audit tolerance indicates a percentage of the relevant audit gas bottle concentration.

In 2005, 47 of 59 workstations (79.7%) that failed the first gas bench audit also failed the second gas bench audit following calibration¹⁴. 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.

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	√

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 2005, 31 of 1,713 workstations audited (1.8%) failed one or more of the items in the gas cap tester audit. The 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.

¹⁴ 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 47 audits that failed the second bench audits are 2.7% of all bench audits and 79.7% of the second bench audits. This is an improvement over 2004, when 6.0% of all bench audits failed the second bench audit.

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 2005, 22 of 1,693 workstations audited (1.3%) 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 2005, 5 of 1,646 workstations audited (0.3%) failed one or more of the items in the OBDII RPM audit.

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:

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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 2005, 7 of 1,689 workstations audited (0.4%) failed one or more of the items in the OBDII Tester audit. All 12 OBDII failures (RPM and tester audits combined) were due to one vendor's intermittent problem communicating with the OBDII simulator and were not due to inaccuracies.

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 2005, 38 of 1,711 workstations audited (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 2005, 141 of 1,758 workstations audited (8.0%) failed one or more of the VMAS dilute O2 sensor audit gases. However, only 28 of the 1,758 of the workstations audited (1.6%) failed for the 15% O2 audit gas and were therefore considered a Critical Audit Failure.

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. 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 2005, 32 of 1,711 workstations audited (1.9%) failed one or more of the VMAS flow points. This is a significant improvement over the 11.2% failure rate in 2003 and over the 3.7% failure rate in 2004.

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 Overall Audit Results

Overall in 2005, 756 of the 1,931 workstation audits (39.2%) failed one or more of the 88 audit items described in previous sections. This is an improvement over the 82.5% failure rate for 2003 and over the 54.9% failure rate for 2004. Also in 2005, 225 of 1,895 workstation audits (11.9%) failed either the first gas bench audit, VMAS Dilute O₂ sensor, or VMAS SAO Flow audits. In 2004, 31.5% of audits failed either the first bench audit or the VMAS audits.

For combined critical gas bench/ VMAS audit items, 103 of 1,895 audited workstations (5.4%) failed at least one of the critical bench or VMAS audit items. This is an improvement over the 13.3% failure rate for 2004 for the critical bench or VMAS audit items.

4.16 Stations Shut Down as a Result of Equipment Audits

In 2005, 30 workstations of the 1,931 workstation audits (1.6%) were shut down during the course of the equipment audit. In these instances, the workstation was locked-out by its own software because it could not pass one of its required calibrations.

5.0 Applus Equipment Audit Results

Applus developed its equipment audit procedures based on the procedures implemented by MassDEP and its audit contractor, TESTCOM.

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 three audit gases.
VMAS Flow	Accuracy check of VMAS flow measurement at three flow rates.

Applus performed a total of 6,802 audits in 2005. 1,549 different workstations (lanes) were audited. 24 Workstations were audited once, 15 workstations were audited twice, 195 workstations were audited 3 times, 565 workstations were audited 4 times, 634 workstations were audited 5 times, 102 workstations were audited 6 times, 13 workstations were audited 7 times, and 1 workstation was audited 8 times.

There are a few areas where MassDEP and Applus equipment audit procedures differ. One instance where procedures differ, the MassDEP gas cap test, is based on two criteria:

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

A gas cap may fail a MassDEP audit for either of these criteria. Applus' audit procedure for the gas cap test 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. In contrast to MassDEP equipment audits, Applus equipment audits replace or repair workstation components that would normally result in an audit failure according to MassDEP criteria. In Table 3 below, an audit is counted as a "failure" if a workstation component fails the Applus audit, or if Applus replaces or repairs a failed component during the audit. Thus, the audit results reported in Table 3 reflect the conditions that Applus found upon starting the audit, not the condition of the equipment upon Applus' completion of the audits.

Table 3 presents a breakdown of results for the individual audit parts and the overall audit result. Although a total of 6,802 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. In other instances, a particular part could not always be audited.

Table 3: Equipment Audit Results 2005

Audit Part	Applus Technologies				MassDEP
	Pass	Fail	Tested	Failure Rate	Failure Rate
Visual Inspection	6,695	37	6,732	0.5%	4.4%
Gas Analyzer Visual Inspection	5,541	1,218	6,759	18.0%	17.1%
Weather Station	NA				21.1%
Leak Check	6,681	106	6,787	1.6%	1.2%
1 st Gas Bench Audit	5,569	266	5,835	4.6%	3.8%
2 nd Gas Bench Audit	NA				79.7%
Gas Cap Tester	6,766	22	6,788	0.3%	1.8%
Inductive RPM Pickup	NA				1.3%
OBDII RPM Pickup	NA				0.3%
OBDII Tester	NA				0.4%
VMAS Visual Inspection	6,543	145	6,250	2.3%	2.2%
VMAS Dilute O2 Sensor	5,690	194	5,884	3.3%	8.0%
VMAS Dilute O2- 15% ¹⁵	5,630	61	5,691	1.1%	1.6%
VMAS Dilute O2- 8%	5,500	190	5,690	3.3%	7.7%
VMAS SAO Flow	3,206	121	3,327	3.6%	1.9%
Overall Audit Result¹⁶	5,046	1,756	6,802	25.8%	39.2%
Combined (Gas Bench + VMAS)¹⁷	6,749	545	6,735	8.1%	11.9%
Critical Audit Failures					
Combined Critical Gas Bench/ VMAS ¹⁸	NA				5.4%
Gas Cap Tester	NA				1.2%
Barometric Pressure ¹⁹	NA				0.0%
OBDII Test System	NA				0.0%

¹⁵ VMAS Dilute O2- 15% is a subset of the audit of the 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). Only failures for the 15% O2 audit gas are deemed a Critical Audit Failure.

¹⁶ To pass the overall audit, the workstation cannot fail any individual audit part.

¹⁷ Combined results from 1st Gas Bench, VMAS Dilute O2, and VMAS Flow audits for each workstation audited.

¹⁸ A Critical gas bench audit failure occurs when a bench fails its first bench audit, is re-calibrated and then fails a second bench audit, immediately after the calibration. Critical VMAS failure occurs when the VMAS fails the flow audit or 15% dilute O2 audit. The Combined Critical Gas Bench/VMAS failure occurs when the workstation has a Critical Gas Bench or VMAS failure.

¹⁹ Barometric pressure must have an error of greater than 10% in order to be considered a critical audit failure.