Control Concept Evaluation
Four-Wheel Dynamometer Requirement as Part of Smog Check
South Coast Air Basin

Scope of Evaluation

Evaluate implementation of a four-wheel dynamometer, loaded-mode Smog Check procedure for vehicles that are incompatible with a two-wheel, loaded-mode dynamometer when equipped with drivetrain features such as all-wheel drive (AWD), four-wheel drive (4WD), or a traction control (TC) system.

Staff's Recommendation

Staff finds this strategy is not cost-effective, or a feasible emissions reduction approach. Investment in a four-wheel, loaded-mode dynamometer system would be very costly, with little chance of return-on-investment and diminishing emissions benefits as vehicles with self-monitoring emissions control systems (OBD II) become more prevalent. In addition, any emissions reductions realized from this strategy would be offset by associated changes in the baseline emissions inventory.

Background and Description of Issue

A portion of the vehicle fleet in California's Enhanced Inspection and Maintenance (I/M) areas that would otherwise be subjected to a dynamometer-based Acceleration Simulation Mode (ASM) test is currently only receiving a two-speed idle (TSI) test, established for California's Basic I/M areas. This deviation in testing is necessary because these vehicles were designed with powertrain systems that are incompatible with current ASM two-wheel dynamometer testing equipment. Because these vehicles, designed with certain AWD, 4WD, or TC systems, require the rotation of all four wheels, they cannot be tested on the current two-wheel, loaded-mode dynamometer system used in California's enhanced Smog Check Program. As such, the benefits of ASM testing over the TSI procedure are not realized for this portion of the fleet.

This paper estimates the additional emissions reductions that would result from the implementation of a four-wheel, loaded-mode Smog Check procedure equivalent in stringency to the current ASM procedure, and also examines the cost-effectiveness and practicality of such a procedure. South Coast Air Quality Management District's (SCAQMD) staff identified the potential of achieving additional emission benefits by requiring these vehicles currently tested by TSI, to be tested on four-wheel dynamometers, assuming that technical and cost issues could be resolved. As part of its adoption of the 2003 South Coast SIP, the ARB agreed to evaluate if achieving additional emission reductions is feasible and cost effective.

Inventory Evaluation

ARB staff's first step was to determine which Smog Check eligible vehicles would benefit from the development of a four-wheel, loaded-mode dynamometer test. The focus is on the potential emissions reductions on this segmented population of TC, AWD, and 4WD vehicles incompatible with ASM testing within the South Coast Air Basin (SCAB).

OBD II's Influence on the Fleet

OBD II equipped vehicles possess the ability to self-monitor nearly every component or system that can affect emissions. When an OBD II system detects a problem, the system will illuminate the vehicle's Malfunction Indicator Light (MIL) located on the instrument panel. The systems are designed to indicate a malfunction once the emissions exceed 1.5 times the standard.

ARB's modeling (EMFAC2002) assumes that drivers observing an illuminated MIL will seek prompt repairs regardless of the timing and/or type of Smog Check test that is required for their vehicles. Therefore, the emissions increases that would otherwise be associated with the malfunctions are considered negligible. ARB staff believes that vehicle owners' inclination to seek prompt repairs is especially true for vehicles still under emissions warranty coverage. The essentially real-time monitoring of emissions performance provided by the OBD II system diminishes the added emission benefits of a more effective four-wheel, loaded-mode Smog Check test procedure.

Changes to California's Smog Check Program now include a check of the vehicle's OBD II system. Thus, for model year (MY) 1996 and newer OBD II vehicles equipped with TC, AWD, or 4WD systems, ARB staff expects little, if any, emissions reductions by subjecting these vehicles to a four-wheel, loaded-mode dynamometer test. Any additional emissions benefits achieved from the use of a four-wheel dynamometer test of these incompatible vehicles lie within the population of pre-OBD II vehicles (pre-MY1996).

Estimated SCAB Vehicle Inventory Incompatible with Two-Wheel ASM Testing

To estimate the number of vehicles that would have need for a four-wheel, loaded-mode ASM test, staff determined what model years would most benefit from the use of a four-wheel dynamometer. Because the number of vehicles MY1982 and older that use TC, AWD, and 4WD systems are very few in number, staff used MY1982 as the lower model year cut point. The upper model year limit of MY1995 was used since newer model year vehicles are equipped with OBD II technology.

To estimate the number of vehicles that would be incompatible with two-wheel ASM testing staff used the April 2004 report entitled, *California Enhanced Inspection and Maintenance (I/M) Program Evaluation* prepared by the Air Resources Board and Department of Consumer Affairs/Bureau of Automotive Repair. This report established that 3.6 percent of vehicles MY1982 to MY1995 are incompatible with two-wheel, loaded-mode testing because they are equipped with TC, AWD, and 4WD systems.

The calendar year (CY) 2005 SCAB population of all Smog Check eligible vehicles MY1982 to MY1995 is estimated at approximately 3.34 million. Of these vehicles, approximately 120,000 are incompatible with two-wheel ASM testing. During CY2005, based on biennial Smog Check requirements, an estimated total of 60,000 vehicles are due to receive a TSI test due to the inability to be tested on a dynamometer.

By CY2010, the total SCAB population of all Smog Check eligible vehicles MY1982 to MY1995 is estimated to decrease to roughly 2.07 million vehicles. Of these vehicles, an estimated 74,000 will be incompatible with two-wheel ASM testing. For CY2010, the number of vehicles expected to receive a TSI test because of this incompatibility is

approximately 37,000. With a population decrease of approximately 9.1 percent annually, by CY2015 it is expected that this SCAB population drops to about 23,000 vehicles.

Assessment of Emissions Benefits by ASM Testing the Affected SCAB Vehicle Inventory
The incremental emissions benefit is the difference between the average emissions of vehicles receiving a TSI test and those receiving an ASM test. ARB staff used EMFAC2002 to determine a per-vehicle benefit of "ROG + NOx" within the SCAB during the summer for CY2010, based upon data from the Basic Program area (assumes TSI for all eligible vehicles) and the Enhanced Program area (assumes ASM for all eligible vehicles). This was performed for the population of MY1982 to MY1995 vehicles.

The following assumptions/facts are relevant to the benefit assessment:

- Emissions calculated with EMFAC2002 version 2.2 (April 2003 activity).
- Smog Check's 30-year rolling exemption was frozen beginning January 2005.
- Staff assumed there were not sufficient TC, AWD, or 4WD vehicles between MY1976 to MY1981 to warrant inclusion in this analysis.
- For this assessment, vehicles subject to enhanced I/M testing are all gasoline-powered and up to 8,500 lb. Gross Vehicle Weight Rating (GVWR).

Table 1, presents the additional emissions benefit that could be realized by including all SCAB MY1982 to MY1995 vehicles outfitted with TC, AWD, or 4WD systems, that are incompatible with two-wheel, loaded-mode dynamometer testing into a four-wheel, loaded-mode dynamometer-based ASM test program. The analysis indicates additional emissions reductions of 0.32 tpd of ROG and 0.49 tpd of NOx.

TABLE 1
Emissions Benefits by Four-Wheel Dynamometer Testing (SCAB CY2010)
of Vehicles Incompatible with Two-Wheel ASM Testing - MY1982 to MY1995

Total Number of Vehicles (CY2010)	2,068,428	
Fleet Emission	Tons per Day	
	ROG	**NOx**
Emissions with Basic I/M Program	101.0	94.3
Emissions with Enhanced I/M Program	83.1	66.9
Additional Benefits for vehicles in Enhanced I/M	**17.9**	**27.4**
per vehicle Emissions Benefit with ASM Testing	8.65E-06	1.32E-05
Number of Vehicles requiring a Smog Check in CY2010	1,034,214	
3.6% of MY1982 to MY1995 vehicles estimated Incompatible with Two-Wheel ASM		
	37,232	
Total Benefits of a four-wheel ASM Test for MY1982 - MY1995 Vehicles tested during CY2010	**Tons per Day**	
	ROG	**NOx**
	0.32	**0.49**

Evaluation of Cost Impacts

To evaluate the cost impacts of requiring a four-wheel, loaded-mode ASM test, staff needed to estimate the increased testing cost to the public as well as the cost to the station owners for installing the equipment.

Testing Cost to the Public

To estimate the additional testing cost of a four-wheel dynamometer-based ASM inspection for vehicles incompatible with a two-wheel ASM inspection, staff used Smog Check data from California's Basic and Enhanced I/M areas. Table 2 shows data from the Bureau of Automotive Repair's (BAR) Executive Summary Report for Calendar Year 2005. Statistical Smog Check data from the Enhanced Area and the Basic Area was used as the basis for the incremental differences associated with four-wheel ASM testing of vehicles currently incompatible with two-wheel ASM testing.

TABLE 2
SMOG CHECK DATA Calendar Year 2005[1]

	Enhanced Area	Basic Area
1st Test Failures by Program Area	14.7%	11.6%
Total Average Repair Cost by Program Area	$185.92	$143.79
Average Inspection Cost by Program Area	$48.91	$33.00
Maximum Inspection Cost by Program Area	$98.00	

As identified on the BAR Executive Summary Report for Calendar Year 2005 the average enhanced inspection cost was reported at $48.91 and $33.00 in basic areas. However, to estimate the typical smog check cost in the SCAB, staff performed a short survey of SCAB stations to determine if they charged differently for the ASM compared to the TSI test. Based on the survey results, staff concluded, on average, the SCAB vehicle owner will likely pay the same price for a smog check whether the ASM or TSI test was performed. Because the smog check pricing structure is "market driven," and there are no established guidelines or restrictions governing inspection costs, staffs expect the inspection cost from a four-wheel dynamometer system to increase. Staff anticipates the smog check inspection cost associated with a four-wheel dynamometer-based test, that would be reasonably accepted by the public, at $80.00 ($80.00 = [average inspection cost $50.00] + [increased inspection cost of a four-wheel system at $30.00]).

Staff used the data from Table 2 to derive Equation 1 which estimates the potential incremental cost increase that would be generated by the upgrade to a four-wheel dynamometer based test for CY2010 within the SCAB. The increased cost was calculated based on the following variables:

- SCAB MY1982 to MY1995 vehicles unable to ASM test during CY2010 (Table 1).
- The estimated difference of a 2-wheel to 4-wheel based inspection cost ($30.00).
- The failure rates ASM and TSI testing (Table 2).
- The costs of vehicle repair from ASM and TSI testing (Table 2).

The calculated incremental cost difference for CY2010 associated with a four-wheel ASM test within the SCAB area is shown in Equation 1.

Equation 1 – Incremental Cost of TSI to ASM Test

$$\left[\frac{37,232\ test}{year}\right]\left[\frac{\$30.00}{test}\right]+\left[\frac{37,232\ test}{year}\right]\left[\frac{14.7\%-11.6\%\ fail}{}\right]\left[\$185.92\right]+\left[\frac{37,232\ test}{year}\right]\left[\frac{11.6\%\ fail}{}\right]\left[\frac{\$185.92-\$143.79}{repair}\right]=\frac{\$1,513,503}{year}$$

[1] BAR Executive Summary Smog Check Report for Calendar Year 2005 – www.smogcheck.ca.gov

Equipment Cost to Station Owners

Staff was able to obtain two estimates of the cost of a four-wheel loaded-mode dynamometer, one at $75,000 and the other at $200,000 (not including in-ground installation, power requirements, building compatibility, etc.). This is approximately two to five times more expensive than the two-wheel, loaded-mode dynamometer used in the current enhanced Smog Check program. The lower cost dynamometer ($75,000) is only capable of performing an ASM steady-state test and if fairly new in the market. The higher cost dynamometer is capable of ASM and transient I/M 240 testing. Transient testing is performed through a driving cycle of accelerations and decelerations that simulates real world driving patterns. A dynamometer that is built to perform transient testing is more expensive than the lower cost ASM only dynamometer. In addition, costs may increase because BAR is currently unable to estimate the cost required to develop the communication interface that would be required to have the four-wheel dynamometer communicate with the current BAR-97 analyzer system/controller.

To better estimate the cost effectiveness of a SCAB four-wheel, loaded-mode dynamometer test, three possible program scenarios were developed based on Smog Check Station type. In the first, it was assumed that all 3,490 smog check stations (2,401 Test/Repair stations and 1,089 Test Only stations per BAR as of CY2006) in the SCAB were to purchase the four-wheel dynamometers. The second scenario assumes Test Only stations (1,089) bought the four-wheel dynamometers, and the third assumed only the market share equaling the percentage (3.6 percent) of vehicles impacted would buy the four-wheel dynamometer equipment. Staff estimated the annualized cost of the equipment assuming a 7-year life for depreciation, an interest rate of 5 percent, and an initial equipment investment of either $75,000 or $200,000.

The estimated annual four-wheel equipment cost for the three SCAB station type scenarios for CY2010 is shown in Equations 2A, 2B, and 2C. The equation shows estimated costs for a low or high cost dynamometer purchase.

Equation 2 – Cost of Equipment by Number of Facilities Impacted in SCAB

Equipment Cost - $75,000

A – SCAB Test/Repair Stations and Test Only Stations

$$\left[3,490\,test\ facilities\right]\left[\frac{\$12,961\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$45M}{year}$$

B – SCAB Test Only Stations

$$\left[1,089\,test\ facilities\right]\left[\frac{\$12,961\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$14M}{year}$$

C – Limited Station Participation Test & Repair and Test Only (estimated at 3.6%)

$$\left[(3.6\%)3,490\,test\ facilities\right]\left[\frac{\$12,961\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$1.6M}{year}$$

Equipment Cost - $200,000

A – SCAB Test/Repair Stations and Test Only Stations

$$\left[3,490\,test\ facilities\right]\left[\frac{\$34,564\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$121M}{year}$$

B – SCAB Test Only Stations

$$\left[1,089\,test\ facilities\right]\left[\frac{\$34,564\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$38M}{year}$$

C – Limited Station Participation Test & Repair and Test Only (estimated at 3.6%)

$$\left[(3.6\%)3,490\,test\ facilities\right]\left[\frac{\$34,564\ annualized\ \text{cost of}\ four-wheel\ dynamometer}{year}\right]=\frac{\$4.3M}{year}$$

Cost Effectiveness

Combining the emissions reduction estimates in Table 1, the incremental testing cost difference from Equation 1, and the equipment costs in Equations 2A, 2B, and 2C into Equation 3 provides the projected cost effectiveness for each scenario for CY2010.

Equation 3 – Cost Effectiveness by Facility

Equipment Cost - $75,000

A - Test & Repair Stations

$$\left[\frac{(\$1.51M+\$45\text{M})}{year}\right]\left[\frac{day}{0.81\,ton\,ROG+NOx}\right]\left[\frac{year}{365\,days}\right]=\frac{\$158,117}{ton\,ROG+NOx}$$

B - Test Only Stations

$$\left[\frac{(\$1.51M+\$14\text{M})}{year}\right]\left[\frac{day}{0.81\,ton\,ROG+NOx}\right]\left[\frac{year}{365\,days}\right]=\frac{\$52,860}{ton\,ROG+NOx}$$

C - Limited Station Participation (estimated at 3.6%)

$$\left[\frac{(\$1.51M+\$1.6\text{M})}{year}\right]\left[\frac{day}{0.81\,ton\,ROG+NOx}\right]\left[\frac{year}{365\,days}\right]=\frac{\$10,643}{ton\,ROG+NOx}$$

Equipment Cost - $200,000

A - Test & Repair Stations

$$\left[\frac{(\$1.51M+\$121\text{M})}{year}\right]\left[\frac{day}{0.81\,ton\,ROG+NOx}\right]\left[\frac{year}{365\,days}\right]=\frac{\$413,130}{ton\,ROG+NOx}$$

B - Test Only Stations

$$\left[\frac{(\$1.51M+\$38\text{M})}{year}\right]\left[\frac{day}{0.81\,ton\,ROG+NOx}\right]\left[\frac{year}{365\,days}\right]=\frac{\$132,462}{ton\,ROG+NOx}$$

C - Limited Station Participation (estimated at 3.6%)

$$\left[\frac{(\$1.51M + \$4.3\text{M})}{year}\right]\left[\frac{day}{0.81 ton\ ROG + NOx}\right]\left[\frac{year}{365\ days}\right] = \frac{\$19{,}850}{ton\ ROG + NOx}$$

Based on the three smog check station scenarios the cost effectiveness is estimated at a low of $10,643 to a high of $413,224 per incremental ton "ROG + NOx" emission reduction. Since the cost of the equipment is annualized over 7 years, it would remain constant through CY2017. It is assumed the rate of vehicles subject to the test is diminishing through the life of the program and is equal to the rate of reduced emission benefits, resulting in the cost effectiveness remaining roughly constant or increasing through the 7 year life of the equipment and program. Therefore, the staff's overall assessment is the program would not be cost effective due to the likely price of the equipment and the diminishing return on emissions.

Impacts on the SCAB Smog Check Industry

Staff predict that the SCAB *Test and Repair Stations* would have little interest, or incentive to purchase the four-wheel, loaded-mode dynamometer equipment. The large capital cost and the limited number of affected vehicles would make it difficult for California's "Mom and Pop" Test/Repair Network to recoup the purchase cost of the four-wheel, loaded-mode dynamometer equipment.

The SCAB *Test-Only Stations* will have a limited return on their investment. With BAR's ability to direct vehicles within the Smog Check Program to the Test-Only Station network, directing limits would make it impossible to capture the entire affected population. Therefore, the test-only station owners have no assurance that the vehicle owners would be directed to them for testing, and would have no guarantee of an increase in business as a result of their investment in the new equipment.

The referee network stations were established to oversee consumer's Smog Check testing complaints, testing of special-construction vehicles, and many other unique Smog Check testing considerations. Testing the affected vehicles through the SCAB Smog Check *Referee Network* would expose vehicle owners to potentially inconvenient appointments and additional travel for an inspection. California law provides BAR the ability to direct vehicles to California's Smog Check Program Referee Network (contracted by BAR). However, the number of vehicles that would be directed would overwhelm the small SCAB referee network of only 12 stations.

Because the average referee station typically schedules appointments approximately 30 days in advance, in 30-minute increments, and with no weekend appointments, any increase directed to the referee network would overwhelm the existing stations. Additionally, vehicle owners would have to travel longer distances resulting in additional time needed to commute to these regionally-located referee stations. Also, as additional vehicles enter the referee network there may also be a significant increase in customer complaints due to the lack of convenient appointments and the increase in test costs associated with the installation of the four-wheel dynamometer equipment.

Conclusions and Recommendations

Staff concludes that for CY2010, within the SCAB, up to 0.81 tons per day of incremental "ROG + NOx" emissions benefits may be achieved from MY1982 to MY1995 vehicles if required to undergo a four-wheel, loaded-mode dynamometer-based test. These vehicles, which cannot be tested on the existing two-wheel ASM dynamometer, are currently receiving the less stringent Basic I/M area's TSI test. These older vehicles, equipped with features such as TC, AWD, or 4WD systems are not equipped with OBD II technology and would be the segment of SCAB's fleet that will benefit from a four-wheel dynamometer-based test.

In CY2005, the SCAB MY1982 to MY1995 vehicles that are incompatible with ASM testing, and are anticipated to receive a TSI test is estimated at about 60,000 vehicles. This SCAB population will decrease to approximately 37,000 vehicles by CY2010, and drop again in CY2015 to approximately 23,000 vehicles. The decrease is approximately 9.1 percent annually.

The cost effectiveness to include these vehicles in a four-wheel dynamometer-based test by CY2010 was broken into three smog check station and dynamometer cost scenarios. If all SCAB Test/Repair and Test Only stations participated utilizing the $200,000 dynamometer (from Equation 2A) the estimated cost effectiveness of a four-wheel ASM program is about $413,130 per ton of incremental ROG + NOx reduced. If only the SCAB Test Only stations participated (from Equation 2B), the estimated cost effectiveness is approximately $132,433 per ton of incremental ROG + NOx reduced. Lastly, if only 3.6 percent of all Test/Repair and Test Only stations (from Equation 2C) were interested in the purchase a four-wheel dynamometer system, the cost effectiveness is estimated at $19,850 per ton of incremental ROG + NOx reduced. It should also be noted, that the long term cost effectiveness will be less attractive as these vehicles continue to leave the fleet and the affected population decreases in size. The cost effectiveness for the $75,000 dynamometer if used in the three scenarios is $158,117, $52,860, $10,643, respectively. However, it would not be safe to assume that only the market share will buy the equipment and participate in the program and that the original estimated cost of $75,000 cost would not increase dramatically once introduced and proper installation needs are assessed.

Given the financial investment required to install a four-wheel dynamometer and the declining number of vehicles that require such test, very few, if any, Smog Check stations (both Test/Repair and Test Only) are expected to purchase the equipment. Also, the option for BAR to have these vehicles tested in the referee network on a four-wheel dynamometer is not viable. Therefore, the staff recommends the following:

- That pre-OBD II vehicles (MY1982 to MY1995) that are incompatible with two-wheel ASM testing should continue to receive a TSI test, since the investment cost of the four-wheel dynamometer equipment is excessive, testing does not result in cost effective emission results, and this vehicle population is decreasing in size.
- That OBD II vehicles (MY1996 to newer) should continue to receive a TSI and an OBD check. This will result in emission reductions that are equivalent to those that could be achieved by testing using a four wheel dynamometer.