An evaluation of CARB's performance tests

What Does Field Testing Show for Assist Vapor Recovery Systems?

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Assisted vapor recovery systems using bootless nozzles were introduced about ten years ago. Since then the California Air Resources Board (CARB) staff has developed a number of test procedures for *certifying* the systems as well as other procedures for performing periodic *field testing.* This subsequent field testing is being done to ensure that the equipment continues to operate within the proper certification specifications.

While the original certification testing is quite elaborate and costly, field tests were designed to be easy to perform and relatively inexpensive. There are three primary field tests: liquid blockage, underground tank system tightness and air-to-liquid ratio (A/L) determination. The latter test indicates whether the vapor pumps in the vapor recovery systems are operating. But does the test actually measure how well the systems are working?

While periodic field tests are simple to perform, the data they generate is limited in scope and does not, in any way, approximate the results of the original efficiency testing. However, California regulators have recently attempted to use the simple A/L test data to extrapolate assist system efficiencies and project fugitive emission rates. The real question is: Can efficiencies and emission rates be accurately determined, considering the simplicity of the test method and complexity of the service-station environment?

In mid-July of this year, during the quarterly meeting of the California Air Pollution Control Officers Association (CAPCOA), CARB released the preliminary draft of a field study performed jointly with CAPCOA. Between January and April of this year, the organizations tested 99 service stations and performed more than 2,000 A/L tests on assist vapor recovery systems throughout California. CARB staff then extrapolated fugitive emission rates from the test results.

In this article, we will review the test procedures used for certification testing as well as the requirements for periodic A/L testing. An analysis of technical considerations for both tests is followed by a discussion of selected actual data from certification tests that show how real vapor recovery systems perform.

Finally, we will review results of recent A/L testing published by CARB and show whether or not A/L tests have been designed to provide vapor recovery efficiency data, and examine if it is advisable to extrapolate test results in an effort to calculate efficiencies. Do A/L measurements only provide data on *whether* a system is working—or can they be used to show *how well* the system is working?

CARB certification testing

In 1991, CARB proposed a new mass balance test procedure for Stage II Vapor Recovery. Although it was not officially adopted until 1996, TP201.2, *Determination of Efficiency of Phase II Vapor Recovery Systems of Dispensing Facilities,* was used to certify all assist vapor recovery systems currently in use. Much of the certification testing took place in 1993, prior to the mandate for vapor recovery implementation in most non-attainment areas outside of California.

Figure 1 (page 26) illustrates the TP 201.2 test procedure. Detailed measurements of vapor volume, VOC (volatile organic compounds) concentration, temperature and pressure are taken at the specific data points: at the nozzle (point one); between the dispenser and underground piping (point two); and at the vent (point three). For systems using a vent processor, a similar measurement is taken at the processor outlet (point four).

Knowing the volume of liquid dispensed, the collection efficiency can be calculated by comparing VOC collection in the dispenser to losses at the nozzle and the vent. This test, which is performed on at least 100 cars over a period of several days, requires considerable resources and, as a result, is quite costly.

In addition to a determination of efficiency, the test data is also used to calculate the ratio of the volume of vapor collected to the volume of fuel dispensed—the vapor-to-liquid (V/L) ratio. Like efficiency, this value is calculated for every vehicle during the 100-car test.

Efficiency and V/L data from actual 100-car certification tests provide the real measure of how vapor recovery systems perform. They provide actual, not extrapolated, data on the collection of vapors as well as the losses incurred during the collection process.

Air-to-liquid ratio testing

A/L testing provides an easy method for verifying the operation of the vacuum pump in assist vapor recovery systems. During 1993, when most of the assist vapor recovery systems in use today were certified, CARB requested industry input on devising a simple field test to indicate whether the vapor vacuum pump was operating. After nearly a year of proposals and counter-proposals, CARB staff developed a procedure now known as TP201.5, *Determination (by Volume Meter) of Air to Liq-*

uid Volume Ratio of Vapor Recovery Systems of Dispensing Facilities.

The original intent of TP201.5 was as a field test to quickly evaluate the mechanical working status of a vapor recovery system within the specified operating range as measured at the time of certification (with the much more complex and costly 100-car certification test). However, its actual application by CARB and CAPCOA has evolved into a *performance* measure. In effect, CARB staff and CAPCOA have been using the test to calculate vapor recovery efficiency data and to project emission rates.

Figure 2 on page 27 shows the A/L test apparatus for the equipment configuration required for field testing. A T-adaptor is pushed over the nozzle spout, sealing the vapor return passage. The T-adaptor is then connected to an air volume meter (such as a Roots meter). As liquid is dispensed, vapors that normally returned through the outer nozzle spout are replaced by air. This air is sucked through the T-adaptor, the plumbing and the air volume meter, which measures the volume of air entering the system.

The resulting data is the A/L ratio. Local air districts in California, as well as vendors, have developed alternatives to the approved CARB test, usually replacing the expensive Roots meter with other devices.

What does A/L really measure?

Vapor recovery efficiency evaluations (as described above and shown in *Figure 1*) are determined by measuring the ratio of mass collected at the vehicle fill pipe to the total mass of vapors displaced from the vehicle fuel tank during refueling. In order to do this accurately, all absolute physical parameters must be measured for all collected samples.

Conversion to Standard Temperature and Pressure (STP) conditions are made for all volume, pressure and temperature measurements of the samples. In this way, the ratio of the collected mass over the total mass (the total mass is the lost mass plus the mass collected by the vapor recovery system) provides for an accurate measurement of the vapor collection efficiency.

Figure 1: CARB 100-car efficiency test (TP 201.2)

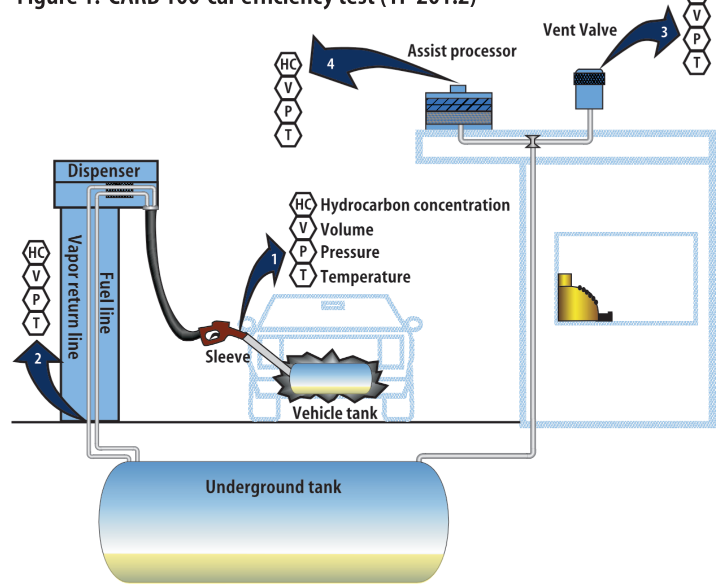
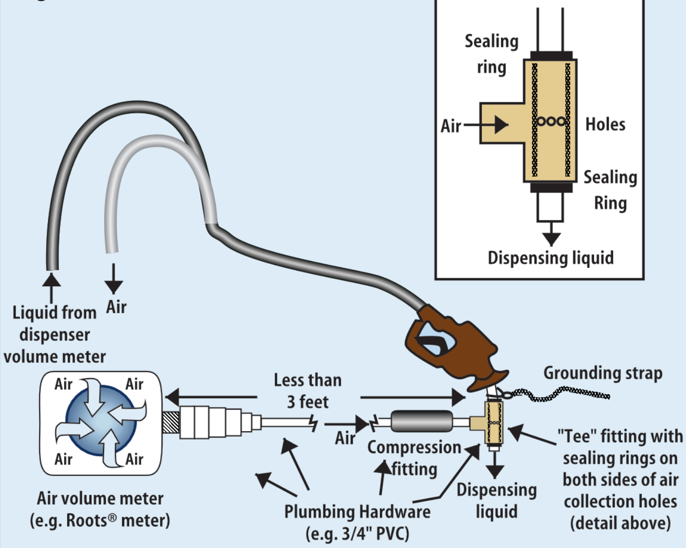


Figure 2: CARB A/L test (TP 201.5)



To allow for variations in vehicle fuel fill-pipe geometry, temperatures of vehicle fuel tanks, underground storage tank (UST) temperature and pressure, atmospheric pressure, and ambient temperature, several measurements are made over a few days. This is done to provide an average efficiency for the current vehicle population and average current conditions. (CARB requires a 100-vehicle matrix representing the vehicle population in California.)

A/L measurements are not as precise as the efficiency measurements. A/L measurements assume that the vapor recovery system is a positive-displacement pumping system that essentially provides a constant volume ratio of vapors collected to fuel dispensed. Although not all systems work exactly this way, the assumption is still considered valid for compliance purposes by CARB; and no attempt is made in A/L measurements to convert measured parameters to STP or volumes to mass.

In fact, several factors are not considered during A/L measurements. This directly affects the application of A/L measurements to any efficiency measurement or efficiency correction. These factors are as follows:

- *Air Temperature*—The temperature of air ingested by the vapor pump is not corrected for STP. Although a small correction is made when temperatures are within 10 degrees of standard (68 degree F, 528 degree R), each degree deviation from standard has about 0.19 percent effect on the measured value (1/528).

- *Air pressure*—The pressure of air ingested by the vapor pump is not corrected for STP. Again, although a small correction is made when atmospheric pressures are within 10 inches WC (Water Column) of standard atmospheric pressure (29.92 in Hg, 407 in WC), each inch of WC (0.07 in Hg) deviation from standard has about 0.25 percent effect on the measured value (1/407).

- *Pressure differential between the atmosphere and UST*—In addition to volume corrections due to the current atmospheric pressure, all vapor recovery systems depend at least slightly upon the pressure differential between the dispensing nozzle (atmospheric for A/L measurements) and the UST. Although it may be assumed that the A/L measurement conditions are similar to conditions at the time of certification testing, varying barometric pressures could affect the A/L value. Low pressure vapor recovery systems that control the UST pressure by slight variations in V/L during refueling (as a function of UST pressure) will show the same variations in A/L measurements.

- *Density of fuel (gasoline)*—Gasoline is assumed to have a certain density that affects the application of A/L measurements to efficiency calculations or lost-mass corrections. Gasoline density varies significantly with temperature with an average specific gravity of 0.725 (for an average blend of gasoline) at about 68 degrees F. The specific gravity of the same blend of gasoline is about 0.755 at 0 degrees F and about 0.710 at 100 degrees F. Although UST temperatures (and thus the fuel in the UST) remain fairly constant over time, many A/L measurements do not allow for enough fuel to be dispensed to ensure that the dispensed fuel attains the UST temperature rather than the ambient forecourt temperature. In addition to temperature, seasonal changes in gasoline vapor pressure affect densities.

- *Design variations*—Variations in the design of the T-adaptor and in the dimensions of the associated piping will produce differing results by changing the pressure drop across the experimental equipment. In order to eliminate this variable, all equipment must be standardized. While this was done for the reported field tests, it is not general practice for every inspecting agency.

- *Aspiration of air*—Excess air may be aspirated by the vapor pumps of some systems. A/L measurements assume that all vapor collected is from the vehicle tank. The only valid comparison for an efficiency calculation requires the use of mass, not volume, of VOC collection.

CARB has proposed that a direct linear relationship exists between A/L measurements and efficiency for the purposes of estimating the emission impact due to faulty equipment in the field. If such a direct linear relationship were valid, the required 100-car efficiency test could be replaced by direct A/L ratio determination.

Attaining 100 percent efficiency would require the A/L to be exactly 1.00 during vapor collection. As proven by numerous observations of many vacuum-assist vapor recovery systems, this relationship is just not valid, and careful analysis of the vapor collection process over many different environmental and vehicle parameters confirms this conclusion.

The use of A/L measurements is certainly valid for compliance checking, since the A/L value can indicate, within a range of values, whether or not a system is working within the mechanical parameters measured at the time of certification. However, A/L measurements are not valid for efficiency measurements, and care must be taken when extrapolating efficiency variations (other than very gross effects) or in determining lost-mass values based upon A/L values alone.

Table 1: 1993 average 100-car certification test values

Manufacturer	V/L	Efficiency
A	0.94	97%
B	0.99	98%
C	1.15	96%

Actual V/L data from 100-car tests

For this investigation, we have reviewed test data from three actual certification tests of assist vapor recovery systems from manufacturers A, B and C. These tests were all performed in 1993, during the period when most of the currently available equipment was certified.

Normal data trends indicate that at low V/L values, collection efficiency should be low. The efficiency should increase with increasing V/L values up to a point at which the excess vapor returned will overcome the UST system's capacitance and result in excess vent emissions (which will have a negative effect on efficiency).

Since data from each of the three systems can only be compared to other data from within its own set, we have provided average V/L and efficiency data from the respective 100-car efficiency tests in *Table 1*.

Table 2 presents selected outliers (data outside of the norm) from each data set (i.e., manufactuers A, B and C), grouped in order of increasing V/L. The data clearly substantiates our contention that process variables resulting from a dynamic system far outweigh any ability to predict efficiency from a liquid and vapor volume measurement. The actual data shows high efficiencies at low V/Ls and conversely, low efficiencies at high V/Ls.

Most recent CARB A/L testing report

During January-April 1999, CARB staff and CAPCOA performed field inspections at 99 assist vapor recovery sites throughout California. In addition to inspecting all of the equipment and reviewing station maintenance procedures, more than 2,000 A/L tests were performed on two different system types.

CARB staff then averaged all failed tests to arrive at average low and high A/L values for each system. Next, an actual average efficiency for failed A/L systems was calculated by taking the ratio of the failed A/L value to the value certified, assuming that the certified A/L value occurs at 95 percent efficiency.

Using a VOC recovery rate of 7.98 pounds/1000 gallons at 95 percent efficiency, CARB staff calculated VOC losses for both systems, assuming they account for 55 percent of the five billion gallons of annual California throughput. Estimates for total additional fugitive emissions are 6.6 tons/day for the two systems. While the report doesn't address balance systems specifically, this calculation appears to assume that the remaining 45 percent of gasoline volume in California is dispensed through balance systems at a 90 percent in-use efficiency.

The use of A/L testing and efficiency data

There are many potential problems with CARB's projection of fugitive losses. The most important dilemma, of course, is the fact that the A/L test was never designed to provide performance data. As we discussed above, very basic engineering principles should preclude using the test for estimation of efficiencies and emission rates.

In addition to the fundamental problem with the use of A/L data, calculations made by CARB are very rough approximations that

Table 2: 1993 certification test V/L data exhibiting unusual trends

A		
Test #	V/L	Eff. %
102	0.75	90
57	0.79	89
103	0.89	100
104	0.89	100
36	0.91	85
12	0.91	98
51	0.93	99
14	0.96	90

B		
Test #	V/L	Eff. %
55	0.73	99
60	0.85	94
33	0.93	77
34	0.94	99
5	0.98	76
61	1.00	91
3	1.31	94

C		
Test #	V/L	Eff. %
105	1.06	99
77	1.06	88
110	1.07	98
76	1.07	97
73	1.09	100
59	1.09	82
30	1.10	76
112	1.13	70
80	1.06	87
15	1.16	79
21	1.16	78
10	1.23	85
71	1.28	100
101	1.47	80

"...the A/L test was never designed to produce performance data."

seem to be designed to make assisted systems look as inefficient as possible. Is this being done to discourage the use of assisted vapor recovery systems using bootless nozzles and to encourage the use of balance systems?

It is important to note that A/L failure rates varied greatly among various districts, as did gasoline throughputs. Emissions data should be calculated on a district basis rather than averaged for the entire State.

In addition, the vapor recovery systems tested were not certified at 95 percent but, rather, they were certified to an efficiency of *at least* 95 percent. Actual certification efficiencies should be used to calculate average efficiencies for failed systems and the corresponding losses. Using data from certification tests, as shown in *Table 1*, reduces CARB's calculated fugitive emissions by almost 20 percent.*

Since current A/L procedures do not provide for accurate measurements of a system's efficiency, it is not possible to accurately determine a system's vapor collection efficiency by a simple linear relationship to measured A/Ls. A/L measurements will produce "rule of thumb" indications of the vapor collection efficiency, but cannot produce an accurate fuel-vapor mass-loss estimate without careful and detailed evaluation of the collected data.

In fact, actual data from CARB's 100-car efficiency tests show that high efficiencies can be achieved at low V/Ls while low efficiencies can have high V/Ls when testing real vehicles. Using CARB's current approach of extrapolating emissions from A/L data, many of the fueling episodes shown in *Table 2* would have resulted in failed systems with high emissions predictions when, in fact, they achieved high collection efficiencies.

The moral of this somewhat lengthy story is quite simple. It is generally taught in Engineering 101: Don't extrapolate physical tests and their data beyond the boundaries within which they were established. CARB's and CAPCOA's use of the A/L tests to measure performance does *not* provide an accurate reflection of the performance of assisted vapor recovery systems using bootless nozzles in California—or, for that matter, anywhere else.

Biography. . . . . . .

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* *To illustrate this calculation, when working with data from Manufacturer B, average efficiencies will be 98 percent, rather than 95 percent at average A/L. The VOC recovery rate of 7.98 pounds per thousand gallons at 95 percent must now be adjusted to 8.23 pounds per thousand gallons.*