MEMORANDUM

To: Aaron Lowe, AAIA

From: Tom Darlington

Date: April 13, 2005

Subject: Review of ARB's Emission Benefits for Vehicles with Extended Warranties

Hyper Anemo™

The emission control system warranty regulations in California require that vehicles be "free from defects in materials and workmanship which cause the failure of a warranted part ...for seven years or 70,000 miles, whichever first occurs." [1] There are two classes of vehicles, however, that have extended warranties. The first are extended warranty Super Ultra Low Emission Vehicles (SULEVs), and the second are Partial Zero Emission Vehicles (PZEVs). Extended warranty SULEVs are allowed to use a lower non-methane organic gas emission (NMOG) standard value in estimating compliance with the NMOG averages than "normal" SULEVs, and PZEVs are allowed to build credits to meet the California ZEV mandate. The extended warranty requirements are 15 years 150,000 miles, which ever occurs first. [2] There are other differences in these vehicles in addition to the warranty differences, but the basic exhaust emission standards are identical for normal SULEVs, extended warranty SULEVs, and PZEVs.

A key question is what are the emission benefits of extended warranties? This memo attempts to answer that question, using information from the California ARB on-road emissions model, and reviewing methods used to estimate emission benefits of various technologies, as discussed in various ARB reports.

This review is organized into the following sections:

- Summary – this section summarizes our findings
- Background – this section describes the regulatory requirements for SULEVs, extended warranty SULEVs, and PZEVs
- Emission Benefits of Extended Warranty SULEVs and PZEVs – this section describes our use of the ARB EMFAC model to quantify the emission benefits of these vehicles, to the extent possible
- Critique of Methods – this section reviews the methods used by the ARB to estimate the emission benefits of PZEVs

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Summary

AIR's review of California's EMFAC model and various reports on modeling methods revealed the following:

1. The EMFAC model does not include a projected roll-out of SULEVs with extended warranties, and therefore, no in-use emissions of these vehicles are estimated in the model. Either the staff believes that their emissions will be the same as SULEVs without extended warranties (and thus, there are no in-use emission benefits to extended warranties for these vehicles), or the staff believes no manufacturer will utilize this option. However, it is very unlikely that the staff believes no manufacturer will utilize this option, or they would not have included it.

2. The EMFAC model does show emission benefits of PZEVs relative to Normal SULEVs. Over a 200,000 mile vehicle life, PZEVs are estimated by the model to have the following emission reductions with respect to Normal SULEVs:

   Total TOG (includes evaporative emissions) : 6.6 lbs
   CO : 35.3 lbs
   NOx : 2.4 lbs

3. There are actually two requirements that could be contributing to the above PZEV benefits. One is the 150,000 mile durability standard that the manufacturers must meet, and the second are the warranty requirements. ARB did not estimate separate, incremental benefits for each of these two requirements. If the warranty requirements were eliminated, presumably, there would still be benefits to the durability standard, and these may be the same as the combined warranty/durability requirements.

4. A review of the methods used by the ARB to estimate these emission reductions for PZEVs reveals that ARB did not use any data on the likelihood of vehicles getting repairs while under warranty to make this assessment. ARB just made simple modeling assumptions, for example, ARB assumed that vehicles with longer warranties had the same margin with respect to the standard at 150,000 miles as vehicles with shorter warranties have with respect to their standards at 120,000 miles.

5. To fully evaluate the emissions impact of extended warranties would require determining through owner surveys or other means, the difference in the number of emissions-related repairs (and the emissions impact of the repairs) for vehicles under warranty to those out of warranty. The Coordinating Research Council recently conducted a survey of owner responses to OBD Malfunction Indicator Lights (MILs) over a wide variety of model years and mileages. When the final report is released, this study may have information that is useful to answer this question.

Background

The California Low Emission Vehicle regulations contain provisions for extended warranties on two classes of vehicles – Partial Zero Emission Vehicles, or PZEVs, and Super Ultra Low Emission Vehicles (SULEVs) that are warranted for the same length of time as PZEVs. These vehicles, their emission standards, and warranty requirements are described below.

PZEVs

PZEVs can be used to satisfy a certain portion of California's zero emissions vehicle requirements. PZEVs must meet an NMOG standard of 0.01 g/mi and a NOx standard of 0.02 g/mi. The evaporative standard for PZEVs is 0.35 g/day (hot soak + 24-hour diurnal), but fuel-related emissions must be "zero". "Zero" in this case is currently defined as no more than 0.054 g/day or about 15% of the whole vehicle standard.

The California EPA's low emission vehicle regulations require the emission systems of partial zero emission vehicles (PZEVs) to meet their standards at 150,000 miles. Also, the manufactures must agree to extend the limit on high mileage in-use testing to 112,500 miles from 90,000 miles.

SULEVs with Extended Warranty Requirements

Another class of vehicles called super ultra low emission vehicles, or SULEVs, can also be used to meet a certain potion of the zero emission vehicle requirements, if manufacturers agree to the same warranty requirements as for PZEVs. SULEVs meeting their standards at 150,000 miles are also allowed to use a lower NMOG value (0.0085) than SULEVs that are certified to 120,000 miles. A SULEV has the same exhaust standards as a PZEV, but the evaporative standard is 0.5 g/day instead of 0.35 g/day. Another difference with respect to the SULEV evaporative standard is that there is no requirement for maximum fuel-derived emissions for this standard. Similar to PZEVs, warranties for high cost parts for PZEVs are extended to 15 years or 150,000 miles, and the manufacture must agree to extend the limit on high mileage in-use testing to 112,500 miles from 90,000 miles.

A comparison of emission standards and warranty requirements for SULEVs, SULEVs with extended warranties, and PZEVs is shown in Table 1.

Table 1. Comparison of SULEV and PZEV Standards and Requirements								
Standard	NMOG (g/mi)	CO (g/mi)	NOx (g/mi)	PM	Evap (Hot soak + 24-hour diunrnal)	Durability (miles)	Warranty period	Limit on high mileage testing (miles)
SULEV	0.01	1.0	0.02	0.01	0.5 g/day	120K	7 years/70K miles	90K
SULEV, Extended Warranty	0.01*	1.0	0.02	0.01	0.5 g/day	150K	15 years/150K miles	112.5K
PZEV	0.01	1.0	0.02	0.01	0.35 g/day, 0.054 fuel	150K	15 years/150K miles	112.5K

* Credited at 0.0085 g/mi in estimating fleet average NMOG.

The key items to note from Table 1 is that for exhaust emissions, the standards are identical. There are really only differences in the last three items – the durability standard, the warranty period, and the limit on high mileage testing. These items are discussed further below.

Increased Durability

The durability periods are increased from 120,000 miles to 150,000 miles. This is not a warranty issue, rather it means that manufacturers must provide test data on certification vehicles showing that they still meet their emission standards after 150,000 miles of mileage accumulation. Manufacturers therefore make design changes in emissions control systems to ensure that, with good maintenance, the certification vehicles can meet the emission standards for this long of a period.

Warranty Period

The increase in the warranty period is to 15 years and 150,000 miles, whichever occurs first. [1] This means that if major emission parts fail, the manufacturers must pay for the replacement of these parts, instead of the vehicle owners. From an in-use emissions perspective, this does not mean that vehicles that fail are more likely to be repaired, it just affects who pays for the repairs. For example, under the extended warranty period, the onboard diagnostic system determines that an oxygen sensor has failed, then most likely, the vehicle owner will take the vehicle in for repairs. After the repair diagnosis, the owner will find out whether the part is covered under the warranty. It is not likely that if the part is not covered, that the owner would not fix the vehicle, if he/she has gone to the trouble to bring it in for repairs. Only in instances where a vehicle owner finds out that the vehicle is not covered, and therefore does not get the vehicle fixed, are in-use emissions affected. We know of no data on this repair-refusal rate, nor has ARB used any data in estimating emission benefits (more on this later).

[1] The EMFAC model indicates that the average vehicle at 15 years of age has 200,000 miles, so it is likely that the 150,000 mile level would be reached for most vehicles before the 15 year point. The average age at 150,000 miles is 11 years.

Limit on High Mileage Testing

ARB performs in-use testing on vehicles every year. The limit on high mileage testing is 75% of the durability mileage. For vehicles certified to standards at 120,000 miles, the limit is 90,000 miles, but if the durability standard is increased to 150,000 miles, the limit becomes 112,500 miles. This has nothing to do with the extended warranty period, but instead reflects increased manufacturer liability, so manufacturers design emission control systems so that they do not face increased recall liability.

We said earlier that PZEVs have lower emissions than SULEVs. For exhaust emissions, this can only be attributed to one or more of the above three items, since the emission standards are numerically the same.

ARB's Estimate of the Benefits of PZEVs

ARB's on-road emissions EMFAC2002 model can be used to develop emissions over the lifetime of both SULEVs and PZEVs. However, the model does not explicitly model a SULEV with an extended warranty, so this must be estimated from a SULEV.

AIR has developed a version of the EMFAC2002 model that allows us to model only a single vehicle technology over its lifetime. This version of the model was used to estimate lifetime emissions for both a SULEV and PZEV light duty vehicle, or passenger car. The results for Total Organic Gas (TOG), CO, and NOx versus vehicle age are shown in Figures 1-5. PM emissions were identical between both vehicles and are not shown. A key to the figures is as follows:

Figure 1: TOG Exhaust Emissions
Figure 2: TOG Evaporative Emissions
Figure 3: Total Exhaust and Evaporative TOG Emissions
Figure 4: CO Emissions
Figure 5: NOx Emissions

Each figure shows emission rates in g/mi versus age for both SULEVs and PZEVs. Also shown on the plots is the mileage accumulation versus age.

Figure 1

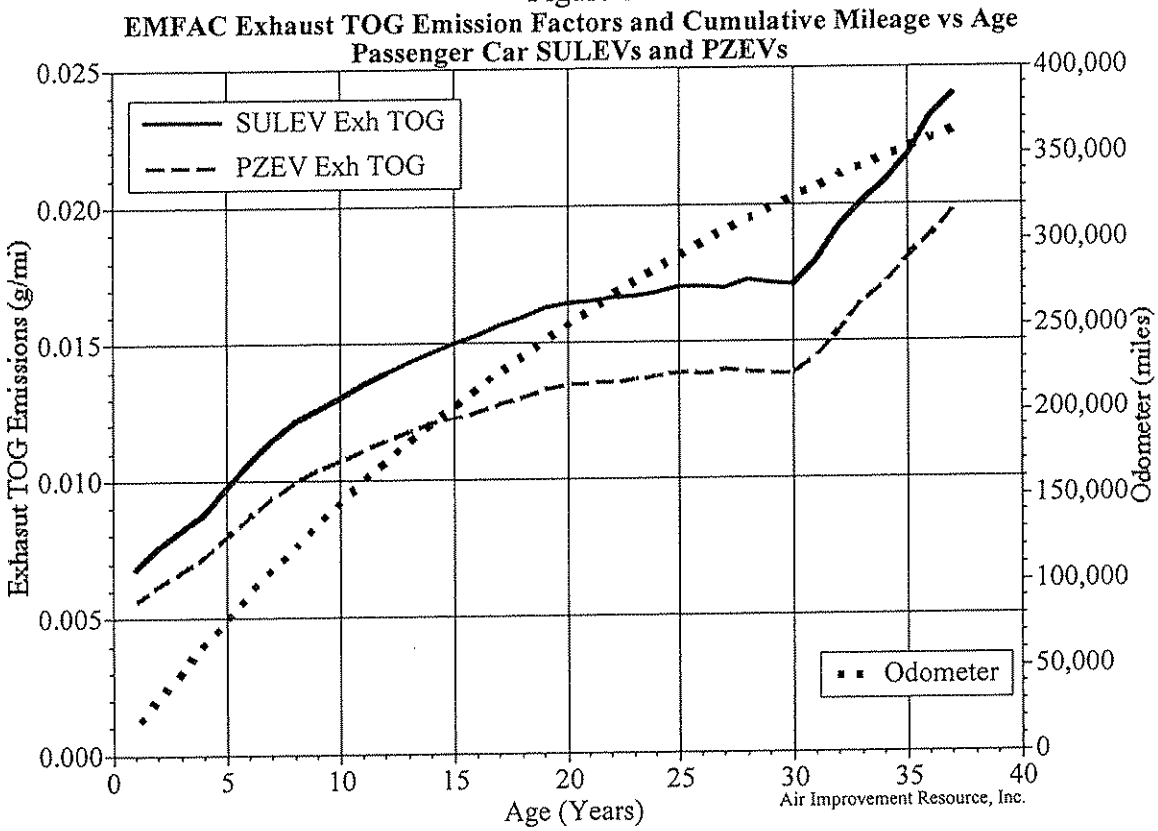

Figure 2

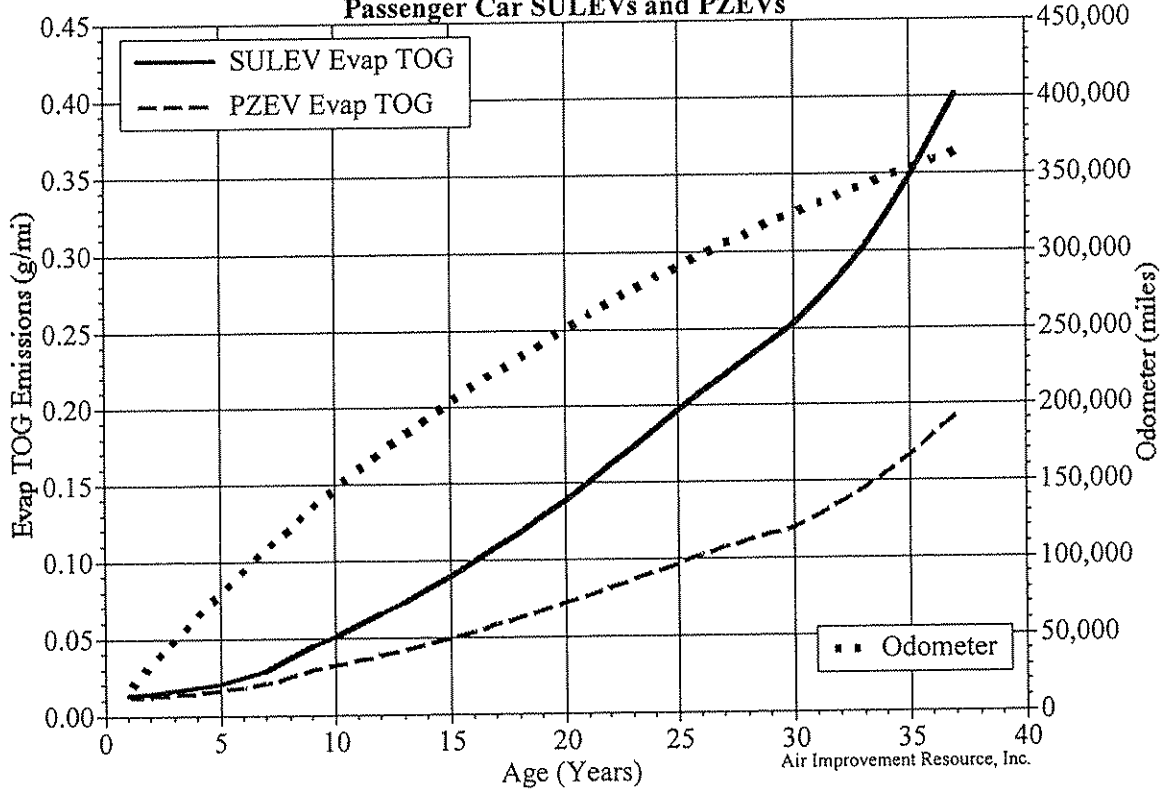

Figure 3

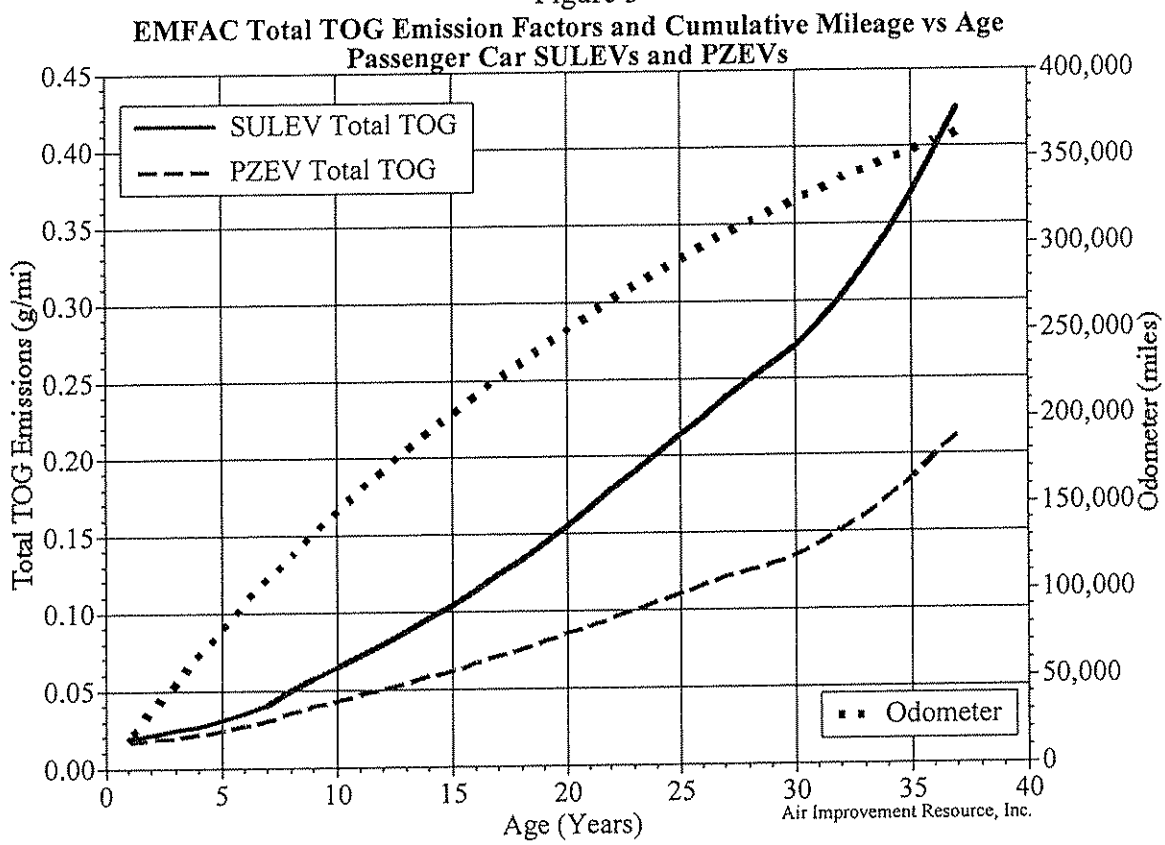
EMFAC Total TOG Emission Factors and Cumulative Mileage vs Age
Passenger Car SULEVs and PZEVs
SULEV Total TOG
PZEV Total TOG
Odometer
Total TOG Emissions (g/mi)
Odometer (miles)
Age (Years)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
0
5
10
15
20
25
30
35
40
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Figure 4
EMFAC CO Emission Factors and Cumulative Mileage vs Age
Passenger Car SULEVs and PZEVs

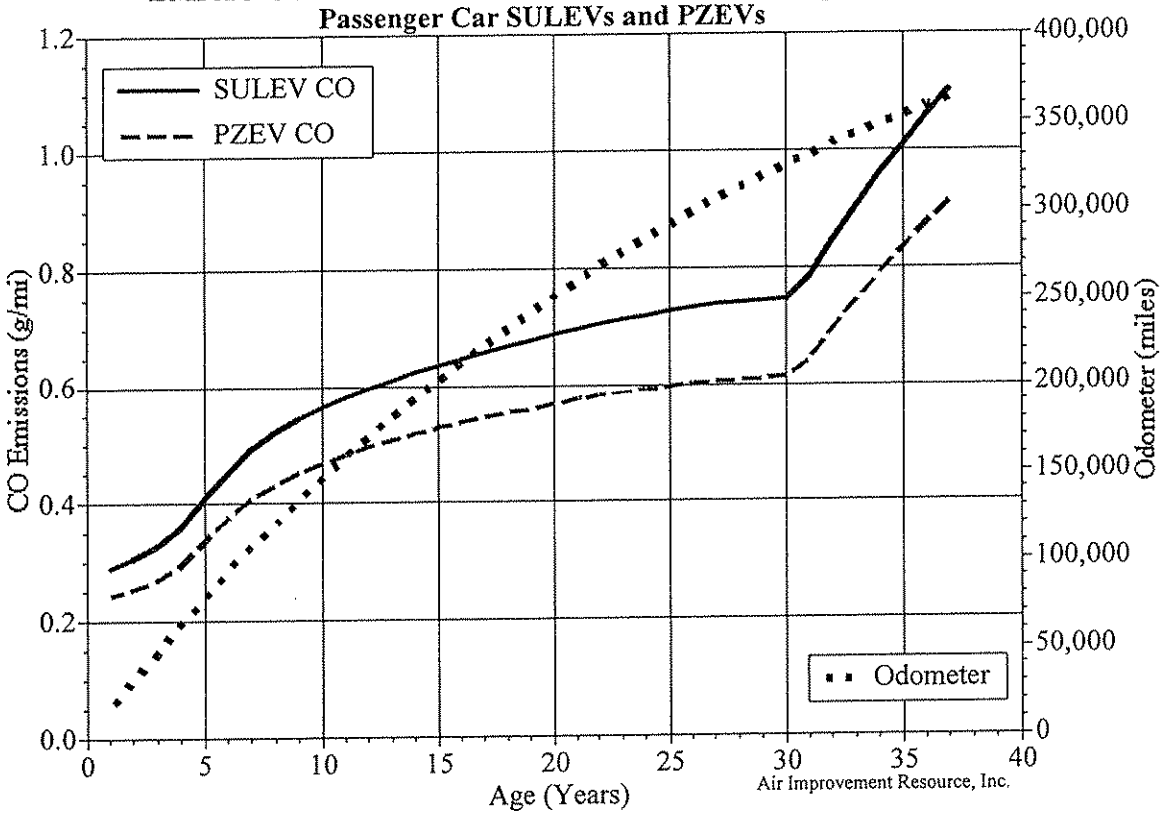
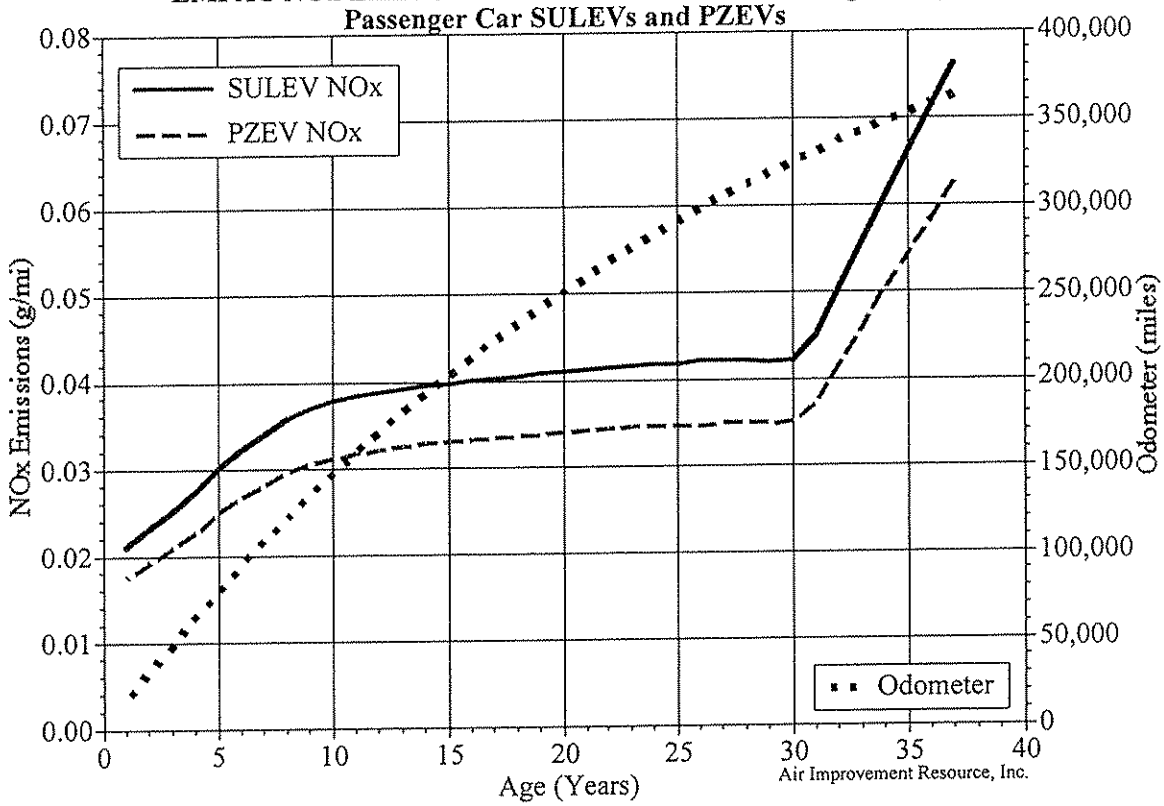


Figure 5
EMFAC NOx Emission Factors and Cumulative Mileage vs Age
Passenger Car SULEVs and PZEVs



The emission lines in the preceding figures include all in-use factors such as corrections for ambient temperature, speed, deterioration, off-cycle operation, starts and other factors. As a result, the emissions in the figures are not necessarily directly comparable to the emission standards, which are conducted over a carefully defined test procedure (the FTP), and under a very limited set of conditions.

The figures show that the emissions for both SULEVs and PZEVs are expected to increase with age and mileage due to emission system deterioration.

- For exhaust TOG, emissions start at about 0.006-0.007 g/mi, and increase to 0.016 g/mi at 20 years of age.
- Evaporative TOG includes a number of different evaporative components. A breakdown of these components is shown in Attachment 1 for both PZEVs and SULEVs. Evaporative emissions start at 0.02-0.03 g/mi, and continue increasing. The deterioration rates are fairly high compared to exhaust emissions, probably mostly due to the influence of the rate of growth of liquid leakers.
- NOx emissions start at about 0.02 g/mi for both PZEVs and SULEVs and increase to about 0.04 g/mi at 20 years.

The figures also show that the emissions of a PZEV are slightly lower than a normal SULEV. ARB's rationale for this is discussed in the next section.

Lifetime Emissions of SULEVs and PZEVs

We estimated the lifetime emissions of a SULEV and PZEV. These estimates assume the average vehicle lasts for about 15 years and accumulates about 150,000 miles before being retired.[2] The results are shown in Table 2.

Table 2. Lifetime Emissions (Undiscounted) of SULEVs and PZEVs (lbs)

Pollutant	SULEV	PZEV	Difference
Exhaust TOG	3.21	2.65	0.56
Evaporative TOG	8.32	6.28	2.04
Total TOG	11.53	8.93	2.60
CO	134.8	112.4	22.41
NOx	9.65	8.05	1.6

The results show exhaust and evaporative benefits for TOG, and exhaust CO and NOx benefits for a PZEV. The evaporative TOG benefits are 3.6 times the exhaust TOG benefits. All of the evaporative benefits are coming from the ARB assumption that PZEVs will have a lower fraction of "liquid leakers" than SULEVs. We think the main reason for that is the need to meet the 0.054 fuel standard, and not the 150,000 mile durability requirement, but there is no ARB documentation on this point. This is discussed further in the next section, but for this analysis we will ignore the evaporative benefits of PZEVs. The CO benefits are not usually used in cost-effectiveness calculations. For exhaust TOG and NOx, the sum of the benefits is 0.56 lbs + 1.6 lbs, or 2.2 lbs.

We have been unable to find cost information for the extended warranties, durability standards and increased test limits, but if we assume that this "package" costs consumers $100 per vehicle in new vehicle cost, then the TOG + NOx cost effectiveness of the package is in excess of $91,000 per ton. This is about 4 times the typical limit of cost effectiveness that the staff considers when evaluating reductions in ozone precursors.

A SULEV with an extended warranty is allowed to use a 0.0085 g/mi NMOG level in the NMOG average calculation. This is a 15% reduction in emissions from the 0.01 used for a SULEV without extended warranty. If we assume the same 15% reduction for both TOG and NOx, the lifetime emissions benefit of a SULEV with an extended warranty relative to a SULEV without this extended warranty is 0.48 lbs of TOG and 1.45 lbs of NOx, for a total of 1.93 lbs. If this too costs the consumer $100 per car, the cost effectiveness exceeds of $100,000 per ton.

[2] Use of EMFAC mileage accumulation estimates a lifetime mileage of 200,000 miles. However, recent analyses by Sierra Research (see "Mileage Accrual and Full-Life Mileage of Vehicles in California", presented by Frank DiGenova at 15th CRC On-Road Vehicle Emissions Workshop, April 4-6, 2005) indicates that the EMFAC estimates do not account for vehicles that are retired during the year, and should. Alternative lifetime mileage estimates from a number of sources indicate that the average mileage a vehicle is retired is closer to 150,000 miles.

ARB's Methods and Data for Estimating Extended Warranty Benefits

The information in Table 1 shows that there are three aspects to PZEVs and extended warranty SULEVs that makes them potentially different than "normal" SULEVs – increased durability standards at 150,000 miles, an increased limit on high mileage testing, and a longer warranty.

PZEV Exhaust Emissions

There is no documentation available from the ARB on the development of PZEV emission rates, but according to the staff, concepts are similar to the techniques used to develop the emission rates for ULEVs and SULEVs. [3,4] The in-use exhaust emissions of PZEVs are derived from "normal" SULEVs. Only the 150,000 mile durability standard is used in estimating the exhaust emission changes for PZEVs; the increased limit on high mileage testing, and the extended warranties for parts are not explicitly included in this analysis.

Basic Emission Rate Methodology

In the EMFAC model, ARB divides vehicles by emitter regime (or emission level), and estimates the emissions of the various emitter regimes. ARB also estimates growth rates for the emitter regimes, and the overall emission rate at any mileage or age for a particular vehicle type is the combination of the emitter regime frequencies and the emission of the different emitter regimes. For example, the emitter regimes used in the model are normal emitters, moderates, highs, very highs, and supers. All technologies in the model are a combination of these regime types.

For a simple emission standard change from one standard to a lower standard with no change in durability standard, ARB models the effects of the standard by reducing the emissions of the different emitter regimes by the ratio of the emission standards. For example, if the new standard is 0.1 g/mi and the previous standard is 0.2 g/mi, then the emissions of normals, moderates, highs, very highs, and supers for the new standard are reduced by 50% (0.1/0.2). Usually, the rate of growth of the emitter regimes is assumed to be the same with the new standard as with the old standard.

With PZEVs the situation is different, because there is no emission standard change, only a change in the durability period (from 120,000 miles to 150,000 miles). The process used by the ARB for this case is as follows:

1. The emissions of SULEVs (with all emitter regimes combined) are compared to their standards (for each pollutant) at 120,000 miles.

2. ARB then assumes that PZEVs have the same percent relationship to the standards (with all emitter regimes combined) at 150,000 miles as SULEVs have at 120,000 miles. ARB then makes an adjustment to all of the zero mile levels of the different emitter regimes so that this works out, approximately.

This process is further illustrated in Attachment 2.

Aside from the math, which can be a little confusing, when ARB evaluates the emissions of a PZEV relative to a SULEV, the only factor that is taken into account is the change in the durability standard from 120,000 miles to 150,000 miles. No analysis is performed of the impact of an extension in warranty levels for major parts, and no analysis is performed of the impact of the increased limit of high mileage testing. Thus, one could say that ARB has estimated no in-use emissions benefit for the warranty and high mileage testing extension. Put another way, if the extension in warranty, and/or the increased limit of high mileage testing were eliminated, there would be no reason to change the emissions of PZEVs, because the emissions analysis only seems to be tied to the relative durability standards of 120,000 and 150,000 miles.

PZEV Evaporative Emissions

For PZEV evaporative emissions, the diurnal + hot soak standard is 0.35 g/test, with no change in the running loss emission standard (0.05 g/mi). According to the staff, they reduced the hot soak emissions, diurnal emissions and running loss emissions by the ratio of the diurnal emission standards of 0.35/0.5. No changes were made to running losses, however, the fraction of liquid leakers is assumed to be less for PZEVs than for SULEVs. The auto industry made this the point with the ARB regarding the first EMFAC2002 model – that the fraction of liquid leakers should at least be less for PZEVs than for SULEVs, because PZEV systems would have to control fuel-related emissions to 0.054 g/mi, and this would require fewer fittings, improved materials, etc. The industry also argued that running losses should also be lower, but ARB left those the same. No one has data yet showing that the fraction of leakers is less for PZEVs, and obtaining data on the frequency of liquid leakers is quite difficult, due to the fact that some liquid leaks are pressure-induced, and so they are only observed when vehicles are operated (i.e., they cannot be discovered with "parking lot" surveys).

Interestingly, the 0.5 evaporative standard for SULEVs applies at 120,000 miles, and the 0.35 standard for PZEVs applies at 150,000 miles; however, ARB determined the emission benefit by applying the ratio of the standards at two different durability periods. This means that they did not attribute any extra benefit to the 150,000 mile durability standard for evaporative emissions for PZEVs. Thus, there appears to be no emissions benefit to extended warranty, extended upper limit testing, or the durability standard, for evaporative emissions.

References

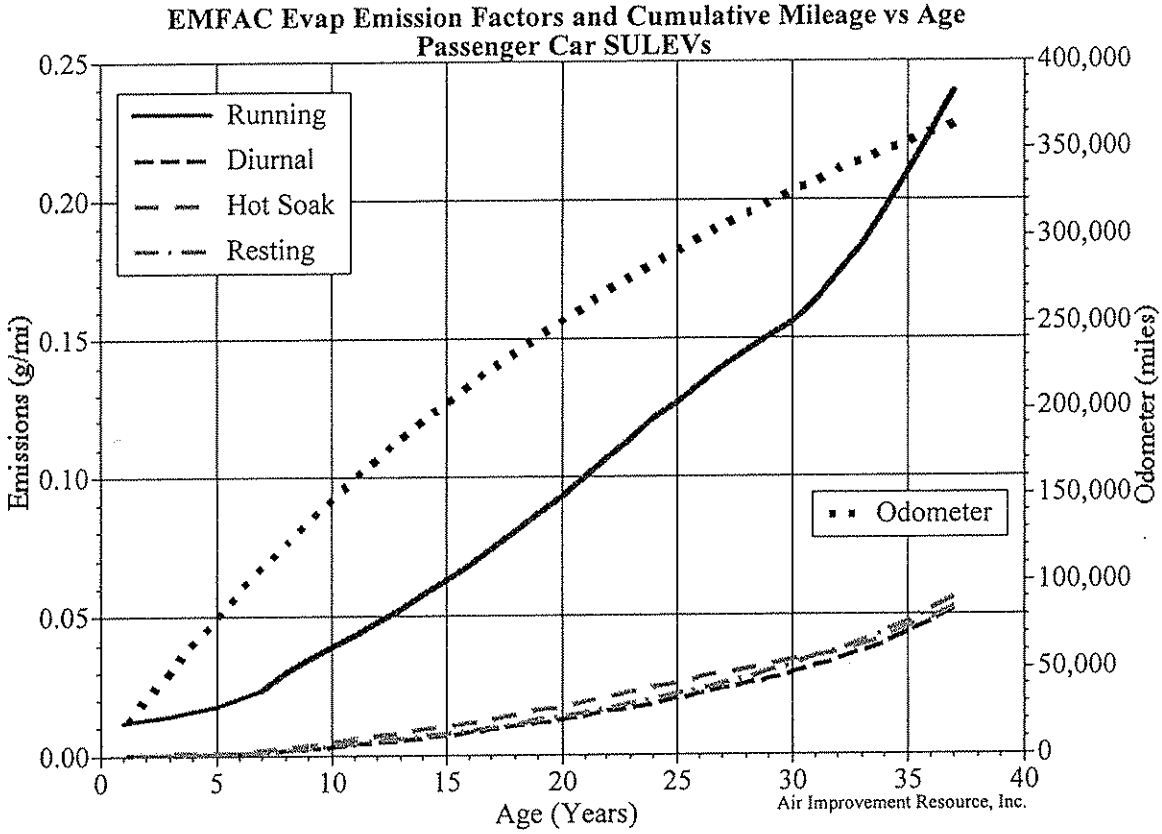
1. CCR Section 2037 and 2038, "Defects Warranty Requirements for 1990 and Subsequent Model Passenger Cars, Light Duty Trucks, Medium-Duty vehicles, and Motor Vehicle Engines Used in Such Vehicles."

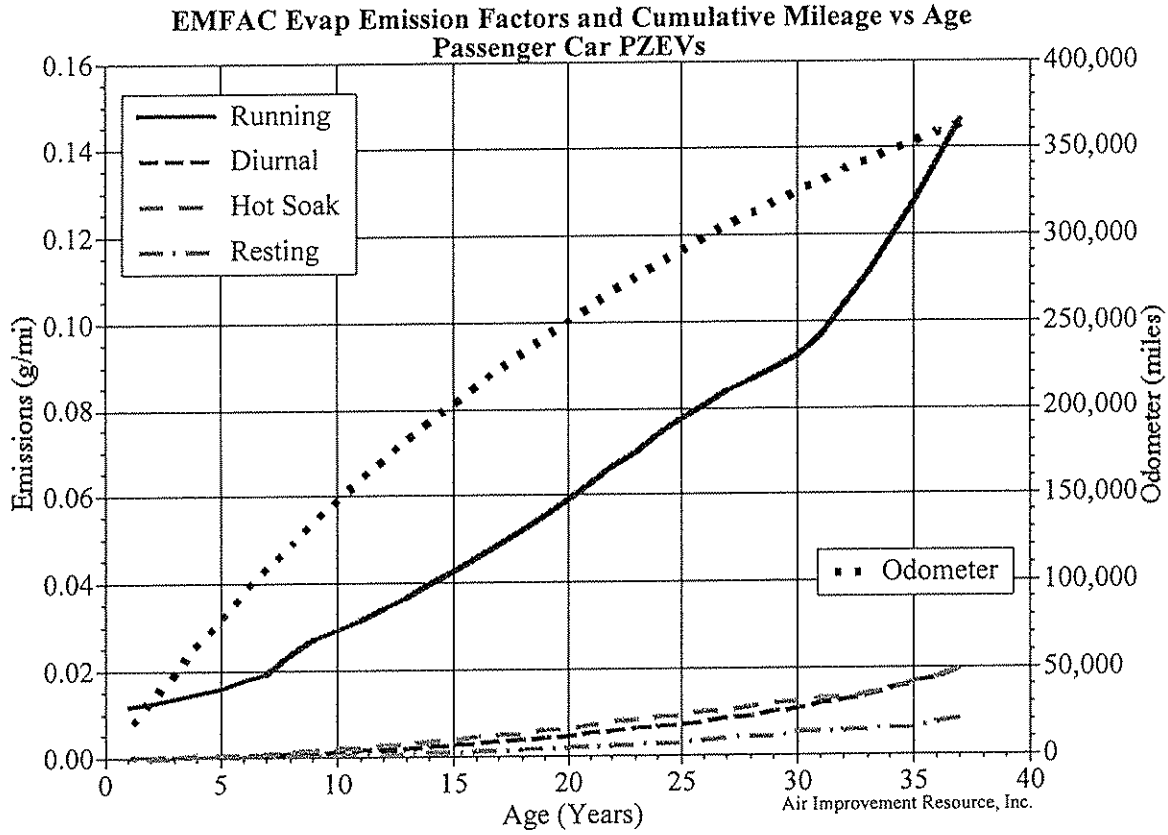
2. "The California Low-Emission Vehicle Regulations", with Amendments Effective August 14, 2004, ARB.

3. E-mail from Mr. Jeff Long to AIR on February 16, 2005.

4. Section 4.9 of Technical Support Document for EMFAC2000, "Methdoology Used in Estimating Emission Rates for Vehicles Certified to the LEV_II Standards", ARB.

Attachment 1
Evaporative Emission Rates for SULEVs and PZEVs




EMFAC Evap Emission Factors and Cumulative Mileage vs Age
Passenger Car PZEVs
Running
Diurnal
Hot Soak
Resting
Odometer
Emissions (g/mi)
Odometer (miles)
Age (Years)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
400,000
350,000
300,000
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Attachment 2