Smog Check Performance Evaluation
Report 2000-02
February 9, 2000

Roadside Inspection Program

State of California Department of Consumer Affairs

Bureau of Automotive Repair
Engineering and Research Branch

BAR ENGINEERING Engineering Clean Air

Report 2000-02

Roadside Inspection Program

Prepared by the

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Roadside Inspection Program

This report summarizes the key aspects of the Bureau of Automotive Repair's (BAR) Roadside Inspection Program. The Program's work plan specifically addresses the following critical elements:

- Determination of sample size and vehicle selection method
- Site selection criteria
- Inspection equipment
- Inspection process
- Quality control and quality assurance

1.0 Determination of Sample Size and Vehicle Selection Method

Roadside inspections were initiated in 1985 by BAR to collect data on overall failures of vehicle emission control systems, tailpipe measurements, and tampering rates, and to analyze and compare this data to that obtained at licensed California Smog Check inspection stations. (Appendix A summarizes the historical achievements of BAR's roadside inspections.) In 1997, BAR began its most comprehensive roadside inspection program to date by conducting about 12,000 inspections per year using Acceleration Simulation Mode (ASM) test equipment.

At the same time, a new sample size and selection method were implemented primarily to ensure that the number of vehicles to be tested was based on the practical aspects of roadside testing (i.e., weather, safe testing locations, staff resources, and functioning equipment), as well as the uncertainties in the mean Federal Test Procedure (FTP) emissions values derived from roadside test results. The motivation for this change was the desire to monitor vehicle emissions reductions in grams/mile based on statistical models developed by Radian International. Radian, under contract with BAR, developed these models to predict FTP emission rates for hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) from measured ASM emissions concentrations. In the December 3, 1997 report, *Methodology for Estimating California Fleet FTP Emissions*, Radian devoted special attention to the models' uncertainty properties so that the relationship between the sample size, vehicle selection method, and the expected uncertainty in predicted FTP HC, FTP CO, and FTP NO_x emission rates would be known. (Radian's sample size tables are included in Appendix B.)

In an effort to optimize the vehicle selection method, Radian compared the benefits of random and stratified sampling. Random sampling is known to have some bias with respect to the California vehicle population. Typically, in a random inspection scenario the older, higher polluting vehicles are under-represented. Since the older vehicle population is a small fraction of the overall California fleet, obtaining an adequate number of older vehicles using the random sample method also results in sampling more newer vehicles. The resulting large numbers of newer vehicles provide little additional benefit in the characterization of their emissions.

In comparison, the stratified sampling method retains only those randomly selected vehicles that meet the optimal sample size required from predetermined model-year ranges. The optimal sample size is designed to produce a smaller variance for the estimated mean than would be achieved using random sampling. In the December 1997 report *Statistical Models to Predict FTP Emissions from Short Test Results,* Radian found that the stratified sampling method increased the fraction of vehicles sampled in the oldest three model-year groups (1966-1974, 1975-1980, and 1981-1986) and reduced the fraction of vehicles in the newest two model-year groups (1987-1991 and 1992 and later). As a result, Radian concluded that stratified sampling was expected to produce lower uncertainties in the predicted mean FTP emission rates for a given sample size. Ultimately, BAR uses both stratified sampling and random sampling to generate roadside emissions measurements.

2.0 Site Selection Criteria

BAR selects test sites that allow for safe vehicle testing and provides a representative fleet sample within each enhanced area, which includes the urbanized areas of Los Angeles, Sacramento, San Diego, and Fresno Counties, and the City of Bakersfield. Test sites are selected from within the enhanced areas from a group of randomly chosen zip codes. The method of drawing specific zip codes for site selection uses a table of seven-digit random numbers and the roll of the dice. Once the random number is selected, it is added to the sampling interval. This sum represents a vehicle in the cumulative count of testable vehicles and is contained within a corresponding zip code. This zip code is then selected for roadside testing. Additional zip codes are selected by continually adding the previously selected random number to the cumulative count until the total vehicle population is exhausted. The only exception to this process occurs when a selected zip code has fewer than 1,000 vehicles. Experience has shown that these are generally post office boxes or other unique situations, such as rural areas where traffic is too light to employ roadside inspection teams productively. In these cases, the zip code selected is eliminated and replaced with the next one with a population of more than 1,000 vehicles. No county or area is significantly over- or under-sampled. The exact methodology for selecting test sites, sample size, confidence level and percent uncertainty is provided in Appendix C.

3.0 Inspection Equipment

The equipment used to perform the roadside inspections (see Figure 3-1 and Figure 3-2) is capable of both ASM and Two-Speed Idle (TSI) testing. The dynamometer and sample system have special features for roadside usage while still meeting accuracy requirements of the BAR-97 equipment used for official Smog Check inspections.

FIGURE 3-1
Ramps attached to dynamometer with EIS in the background.

FIGURE 3-2
Vehicle strapped down to dynamometer during ASM test.

Each BAR-97 emissions analyzer is equipped with:

- A non-dispersive infrared gas analyzer to measure HC in parts per million (ppm), and CO and carbon dioxide (CO_2) in percent.
- A chemical cell oxygen sensor to measure exhaust oxygen (O_2) content in percent.
- Two separate devices: an electrochemical cell and a chemiluminescence analyzer were initially incorporated to measure NO_x in ppm during an ASM test. When valid test results from both NO_x measurement devices were available, BAR selected the electrochemical cell results since all certified BAR-97 systems (at BAR licensed Smog Check stations) use the electrochemical cell. On April 1, 1998 the chemiluminesence analyzer was removed from the ASM roadside testing equipment.
- A dynamometer used to apply a load to the vehicle during the ASM test.

In 1999, the inspection equipment was updated with new hardware (certified BAR-97 equipment) and software. The software was upgraded to include additional features unique to the roadside inspection. The first unit was upgraded on January 6, 1999, two others on February 3, 1999 and the remaining unit was upgraded on August 23, 1999.

4.0 Inspection Process

4.1: Project Personnel

BAR uses specially trained teams of state employees called Air Quality Representatives (AQRs) to perform the roadside emission tests. All roadside AQRs have extensive automotive experience prior to working for the BAR and hold current Smog Check technician licenses. Currently, there are four teams that are based in Sacramento, Pacoima, Paramount, and Ontario.

The number of operational roadside teams varies due to the availability of personnel and equipment. Each team has three AQRs, and each AQR assumes one of the following duties:

1. A greeter/driver – responsible for interacting with drivers, answering program-related questions, and driving the vehicle during the dynamometer portion of the inspection.
2. An underhood inspector – responsible for conducting a visual and functional inspection, if performed, of the vehicle's required emission control systems.
3. A BAR-97 inspection system operator – responsible for operating the emissions analyzer and entering all the applicable data into the analyzer.

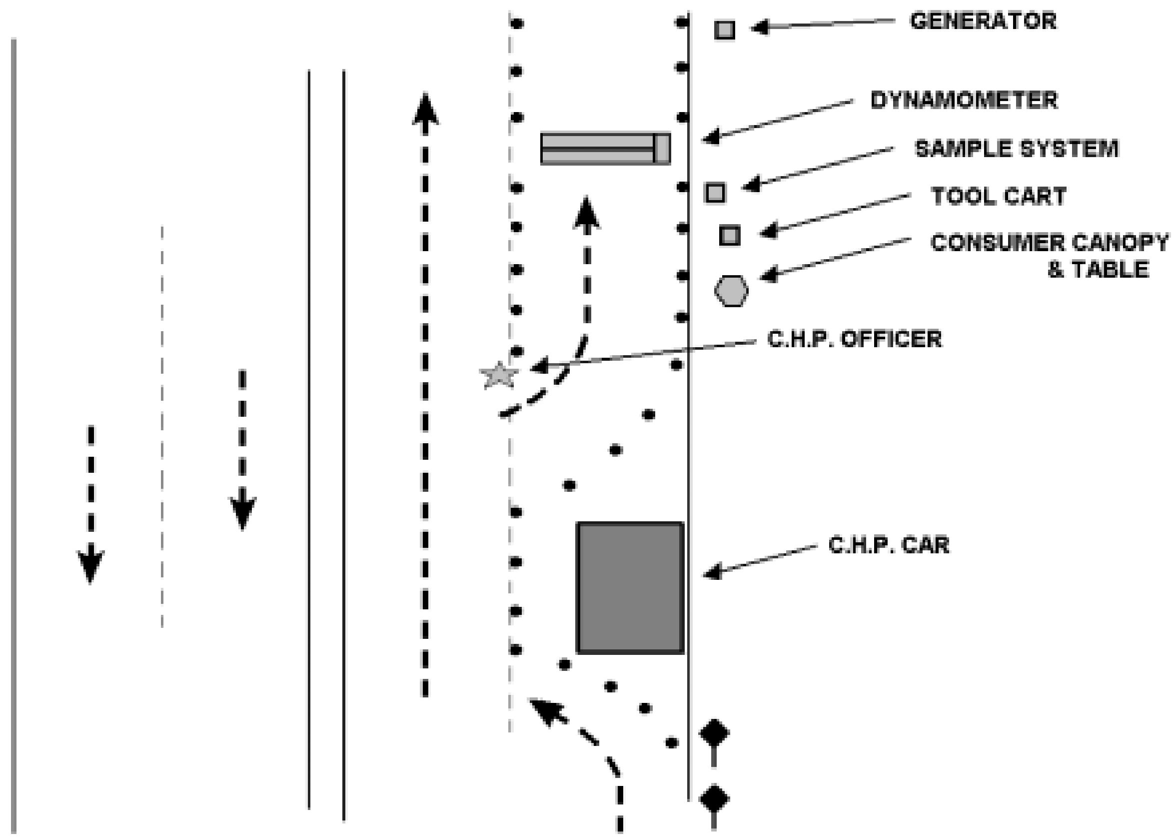
The California Vehicle Code specifies that only a California Highway Patrol (CHP) officer can direct vehicles out of traffic and into test lanes. Therefore, BAR contracts with the CHP to perform the necessary traffic direction and to provide additional security for the Roadside Inspection Program.

4.2: Site Set-Up

BAR performs testing primarily on four-lane surface streets with one lane coned off to provide room for the portable test equipment. To reduce the potential for accidents and injury, BAR chooses roads with a maximum speed limit of 45 miles per hour and uses the curb lane for testing. Moreover, the selected test sites are far enough from corners to allow an adequate merging distance prior to the site and an adequate distance for exiting vehicles to approach traffic speeds before exiting the test lane.

Once the test sites have been selected, the BAR test team meets the CHP officer at the site and, with the officer's assistance, deploys road signs and road cones to establish an inspection lane. Additional road cones are placed within the coned off traffic lane to provide direction for vehicles to exit after the inspection has been completed. Since the dynamometer must be leveled before operating, roads with a crown (curvature of the road) in excess of 14 inches are avoided. Test lane lengths typically range between 300 and 500 feet, depending on traffic speed. After the lane is established, the BAR test team unloads the portable test equipment from the trailer and van, which are then parked at a remote location. Next, two team members assemble and calibrate the inspection equipment while the final member briefs the CHP officer on the random vehicle selection process. Once the equipment is warmed-up, audited, and calibrated, one of the AQRs signals the officer to begin directing vehicles into the test lane. Figure 4-1 shows the layout of a typical inspection site.

FIGURE 4-1
Roadside Test Lane Layout



4.3: Inspection Protocol

Currently, AQR teams use the following test procedure. Using the random sample method, a CHP officer selects vehicles and directs them into the test lane as soon as the test of the previous vehicle is complete. The greeter explains to the driver that the test is part of a survey to evaluate the Smog Check Program and that there are no penalties, emissions-related or otherwise, associated with the test. The BAR greeter also provides the driver with a consumer information handout (Appendix D) that further explains the Roadside Inspection Program. If the driver agrees to participate in the inspection process, the vehicle is inspected. If the driver refuses, the vehicle is released and another vehicle is quickly directed into the test lane. The license plate numbers of vehicles whose operators decline to participate in the Roadside Inspection Program are recorded and entered into a laptop computer for later analysis.

A similar process exists if the team is using the stratified sample method. However, once the vehicle enters the test lane and stops at the appropriate location, the BAR greeter determines the vehicle model-year. Using a worksheet providing model-year stratification, the greeter determines the model-year of the vehicle. If the vehicle is one of the desired models, the driver is asked to participate in the Roadside Inspection Program. If it is not, the driver is thanked for their time and the vehicle is directed out of the lane. Note that every driver has the option not to participate. All testable vehicles receive a 90-second ASM 5015 and a 60-second ASM 2525 test.

Once a driver agrees to have his or her vehicle tested and has exited the vehicle, the following inspection protocol is used:

1. A visual inspection of the vehicle's required emission control systems is performed along with a check of the vehicle's hoses, belts, cooling system, tires and other related safety items to ensure that the vehicle does not pose a safety hazard during testing. The inspection team can choose from the following entries: "Pass", "Fail", "Missing", "Modified", "Disconnected", "Defective", "Not Applicable", and "Incomplete". The "Incomplete" choice was added due to the time constraints involved with roadside testing combined with the unusual placement of some emission components.
2. Functional checks of the ignition timing, exhaust gas recirculation system, and gasoline cap are performed. Note that if the ignition timing and/or the EGR system checks would illuminate the vehicle's "Check Engine" light or the inspection is prohibitively difficult to conduct, the AQR will not perform the functional checks and an "Incomplete" will be entered into the emissions analyzer.
3. The data operator enters the applicable vehicle data and visual and functional inspection results into the analyzer.
4. Light-duty vehicles are strapped down to the dynamometer and a 90-second ASM 5015 test and then a 60-second ASM 2525 test are conducted. For heavy-duty and all wheel drive (AWD) vehicles, a static TSI test is performed.
5. After the emissions portion of the inspection is complete, the vehicle is driven off the dynamometer. The greeter then provides the driver with a computerized printout of the vehicle's emissions readings and answers any of the driver's questions.
6. The driver enters the vehicle, and exits the test lane.

Due to the limited number of Visual and Functional tests performed up to September 1997, the AQR teams began focusing on the collection of Visual and Functional data. At times, this was done by having one team perform only Visual and Functional tests on vehicles while the other teams performed only tailpipe emissions. At other times, no emissions tests were performed and only Visual and Functional tests were performed. During this time, the Visual and Functional data was collected on laptop computers, separate from the tailpipe emissions data. This procedure was discontinued in March 1998

Each roadside team keeps a daily log that is copied onto a floppy disk and, along with the test record file, is forwarded to BAR on a weekly basis. The daily log contains information such as the test team, audit bottle values, audit readings, weather conditions, BAR-97 EIS number, and reasons for aborted tests.

5.0 Quality Control and Quality Assurance

The roadside team members conduct extensive quality control checks throughout the day to assure accurate emissions readings. The team calibrates and "leak-checks" the test equipment every day before vehicle testing begins, and performs NO_x calibrations again at mid-day or after 15 vehicle inspections are performed. Initially, the AQRs performed gas audits three times a day: after the morning calibrations, and before and after the mid-day NO_x calibration. Since August 15, 1997, gas audits have been performed five times a day. In addition, the dynamometer is checked and calibrated daily.

Appendix A

Roadside Historical Achievements

ROADSIDE HISTORICAL ACHIEVEMENTS

Year	# of Inspections	Key Achievements	% Overall Failure Rate	% Emission Failure Rate
1985	1732	Roadside inspections begin	39.3	14.8
1986	2431	BAR assumes roadside management responsibilities from ARB	46.44	22.17
1987	2747	AQR teams determine that it takes 1 hour to set-up/take-down an inspection site	38.1	30.6
1989	3231	Vehicles tested using analyzers transported by large trucks; Inspections performed for final evaluation BAR-84 program	50.1	42.4
1990	2437	BAR-90 analyzers used for the first time	46.4	32.8
1991	2093	Van mounted BAR-90 analyzers used; county inspection sites now selected in proportion to vehicle population	33.1	24.8
1992	2914	Roadside inspections sites now randomly selected	36	28.2
1993	3955	Inspection procedure modified to incorporate "Quick Check" (visual and manual mode idle emission measurements) process	40.4	23.8
1996	Not Available	Loaded mode testing initiated; introduced AQRs	Not Available	Not Available
1997	Not Available	Acceleration-simulated mode roadside testing for program evaluation purposes begins	Not Available	Not Available
1998	Not Available	Started RSD (remote sensing device) testing to quantify those that refuse	Not Available	Not Available
1999	Not Available	Begun using BAR-97 software	Not Available	Not Available

Appendix B

TABLE B-1
Sample Sizes Required to Estimate Fleet Average FTP Emissions

Sampling Type		Random		Stratified	
Test Type		**ASM**	**IM240**	**ASM**	**IM240**
Emission	**Uncertainty in FTP Mean* (%)**				
HC	1	627,000	489,060	270,880	N/A
	2	156,750	122,265	67,720	N/A
	3	69,667	54,340	30,098	N/A
	4	39,188	30,566	16,930	N/A
	5	25,080	19,562	10,836	N/A
	6	17,417	13,585	7,525	N/A
	7	12,796	9,981	5,438	N/A
	8	9,797	7,642	4,233	N/A
	9	7,741	6,038	3,345	N/A
	10	6,270	4,891	2,709	N/A
CO	1	131,397	190,526	94,766	N/A
	2	32,849	47,632	23,907	N/A
	3	14,600	21,170	10,625	N/A
	4	8,212	11,908	5,977	N/A
	5	5,256	7,621	3,825	N/A
	6	3,650	5,292	2,657	N/A
	7	2,682	3,888	1,952	N/A
	8	2,053	2,977	1,495	N/A
	9	1,622	2,352	1,181	N/A
	10	1,314	1,905	957	N/A
NO_x	1	60,625	75,175	54,328	N/A
	2	15,156	18,794	13,582	N/A
	3	6,736	8,353	6,037	N/A
	4	3,789	4,698	3,396	N/A
	5	2,425	3,007	2,174	N/A
	6	1,684	2,088	1,510	N/A
	7	1,237	1,534	1,109	N/A
	8	947	1,175	849	N/A
	9	748	928	671	N/A
	10	606	752	544	N/A

*The desired uncertainties in the mean are stated at the 95% confidence level and are stated as a percent of mean FTP values of 0.95 g HC/mile, 14.8 g CO/mile, and 0.80 g NO_x/mile. For example, to achieve an uncertainty of 0.076-g HC/mile with 95% confidence with a random ASM sample, 9,797 vehicles would be required.

TABLE B-2
Estimated Sample Sizes Required to Detect Changes in the Fleet Average FTP Emissions

Sampling Type		Random		Stratified	
Test Type		**ASM**	**IM240**	**ASM**	**IM240**
Emission	**Uncertainty in FTP Change* (%)**				
HC	1	115,265	102,816	81,394	N/A
	2	28,526	25,445	20,144	N/A
	3	12,549	11,194	8,862	N/A
	4	6,987	6,232	4,934	N/A
	5	4,425	3,947	3,125	N/A
	6	3,041	2,713	2,148	N/A
	7	2,211	1,972	1,562	N/A
	8	1,675	1,494	1,183	N/A
	9	1,309	1,168	925	N/A
	10	1,049	936	741	N/A
CO	1	170,233	173,297	155,449	N/A
	2	42,129	42,887	38,471	N/A
	3	18,534	18,868	16,925	N/A
	4	10,319	10,505	9,423	N/A
	5	6,536	6,654	5,968	N/A
	6	4,491	4,572	4,102	N/A
	7	3,265	3,324	2,982	N/A
	8	2,473	2,518	2,259	N/A
	9	1,933	1,968	1,766	N/A
	10	1,549	1,577	1,415	N/A
NO_x	1	61,066	56,242	55,929	N/A
	2	15,113	13,919	13,842	N/A
	3	6,648	6,123	6,090	N/A
	4	3,701	3,409	3,391	N/A
	5	2,344	2,159	2,148	N/A
	6	1,611	1,484	1,476	N/A
	7	1,171	1,078	1,073	N/A
	8	887	817	813	N/A
	9	693	638	636	N/A
	10	556	512	509	N/A

*The size of the uncertainty in population mean FTP emission rates are stated at the 95% confidence level as a percent of the original mean FTP value whatever it may be. For example, to be 95% confident that the drop in the population mean FTP HC of 10% is between 5% and 15%, that is, 10% ± 5%, for a random ASM sample, 4,425 vehicles would need to be sampled before and after the change in the mean.

Appendix C

Methodology Used for Site Selection

Methodology Used for Site Selection

1. Experience shows that zip codes with less than 1,000 vehicles have difficulty obtaining enough vehicles to test on a typical test day and are, therefore, not used for site selection. Those with over 1,000 vehicles and located in enhanced areas are arrayed in numerical order from the lowest zip code numbers to the highest. Then, the number of vehicles is cumulated by zip codes. The result looks like this:

	Zip code	Vehicles	Cumulative Sum of Vehicles in California Enhanced Areas
The 13,394th vehicle	90000	15,000	15,000
(see step 6)	90001	7,500	22,500
	90007	5,000	27,500
			Total 9,929,509

2. For example, to achieve an uncertainty of 4% in the predicted mean FTP HC emissions in grams per mile with 95% confidence with a stratified ASM sample, Table A-1 shows that 16,930 vehicles would be required. This is divided by 30 (the number of anticipated inspections per team per day) to arrive at the number of sites needed.

$$16,930 / 30 = 565$$

3. The number of vehicles (cumulative sum) is divided by the number of required sites. For example, if 565 sites are needed,

$$9,929,509 / 565 = 17,575$$

17,575 is the sampling interval.

4. A seven-digit number is selected from a random number table to determine the first zip code for site selection. An unbiased way of choosing the number from the table is used, such as rolling dice. For example, the first number rolled identifies a column on the table and the second roll identifies a row on the table. The random number located where the row and column intersect is selected.

5. After the random number is selected, the first set of five digit numbers that contains a value equal to or less than the sampling interval 17,575 is selected. For example, if we see the random number selected

is 9813394, Then 13394 is selected.

6. Using the cumulative table, the zip codes in which the 13,394th vehicle is contained is selected for the sample (see step 1, zip 90000).

7. A table is created which continues to add the sampling interval to the first number selected.

For example: 13,394 + 17,575 = 30,969

The succeeding numbers would be 48,544; 66,119; 83,694, etc.

8. Zip codes are then identified in which the 30,969th, 48,544th, etc. vehicles are located in the cumulative table. When the process is complete, there will be 565 sites selected.

9. BAR selects alternative sites in the event that the original sites are unusable. For example, if we want 10% or 57 additional sites as alternatives, we compute a new sampling interval (9,929,509 / 57), roll the dice anew, and select alternative sites using the foregoing process.

Appendix D

Consumer Information Sheet (English)
Consumer Information Sheet (Spanish)

STATE OF CALIFORNIA
DEPARTMENT OF CONSUMER AFFAIRS
BUREAU OF AUTOMOTIVE REPAIR

State of California Department of Consumer Affairs

CONSUMER INFORMATION SHEET

ROADSIDE EMISSION STUDY

We are inspecting your vehicle today to gather vehicle emissions data for the State of California. This data is only used to evaluate the performance of California's emissions reduction programs. There are no consequences to you for participating regardless of your emission equipment or emission levels. The inspection will be conducted by ASE Certified and Licensed Smog Check Technicians (Air Quality Representatives). Your cooperation in this roadside check is important and very helpful to us.

We will inspect your vehicle as quickly as possible. The inspection should take less than 10 minutes.

We will provide you a copy of the inspection report for your vehicle. The results may be useful to you in that they can point out problems with your emission control system(s). We will also alert you of any other mechanical deficiencies we observe while conducting the inspection. Remember regular maintenance and properly operating smog control systems can significantly reduce smog-forming emissions.

For additional information regarding the roadside emission study, please call toll free 800-952-5210 or BAR's website at www.smogcheck.ca.gov.

THANK YOU FOR YOUR PARTICIPATION!

CLEAN AIR IS GOOD FOR EVERYONE

ESTADO DE CALIFORNIA
DEPARTMENTL SOCIAL DEL CONSUMIDOR
OFICINA DE REPARACION DE VEHICULOS

State of California Department o Consumer Affairs

INFORMACION PARA EL CONSUMIDOR

ESTUDIO DE EMISIONES

Hoy estaremos inspeccionando su vehiculo para reunir datos sobre las emisiones de vehiculos en el estado de California. Estos datos son utilizados para evaluar solamente le efectividad del nuevo programa, en el estado de California. No habra ninguna consecuncia para usted por participar, respecto al equipo de emisiones o de los niveles de emisiones. La inspeccion sera conducida por los Tecnicos con Licencia de Inspeccion de Humo y Certificados por ASE (Representantes De La Calidad Del Aire). Su cooperacion en este estudio es importante y muy benefisioso para nosotros.

Haremos la inspeccion lo mas rapido posible. La inspeccion tomara aproximadamente 10 minutos.

A cambio de su cooperacion, por esperar le daremos una copia de los resultados de la inspeccion. Los resultados talvez podran ser utiles para usted para indicarle problemas en el control del sistema de emisiones. A la ves, le avisaremos si se encuentran otras deficiencias mecanicas mientras hacemos la inspeccion. !Recuerde, con hacerle el manteniminto regularmente, el control de los sistemas de emisiones trabajara mejor y ayudara a reducir la formacion de humo!

Para mas informacion sobre el estudio de emisiones,llame al (800) 952-5210 O Eseribanos en la pagina de internet www.smogcheck.ca.gov.

GRACIAS POR SU PARTICIPATION!

!MANTENER EL AIRE LIMPIO ES UN TRABAJO PARA TODOS!