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Emission Benefits of Cleaner-Burning Gasoline
A Summary of Studies

Introduction

The Air Resources Board adopted the cleaner-burning gasoline regulation in November 1991 based upon studies relating fuel properties to emissions. These studies included the Auto/Oil Air Quality Improvement Research Program and studies conducted by individual oil and automobile companies. In June 1994, a predictive model was incorporated into the regulation to provide refiners additional flexibility in producing cleaner-burning gasoline. This model enables refiners to use a computer program that calculates the emission benefits of fuels with formulations different from the cleaner-burning gasoline standard specifications. Refiners are then free to produce alternative formulations that reduce emissions as well as a fuel that meets the base standards. The predictive model was based on 20 emission test studies that included approximately 1,100 vehicles and 7,700 exhaust emission tests. See attached table. The emission reductions associated with cleaner-burning gasoline as reported in the predictive model staff report are a 17 percent reduction of volatile organic compounds, an 11 percent reduction in carbon monoxide and an 11 percent reduction in oxides of nitrogen.

Over the last several years, additional studies have been conducted. All of these studies support the earlier evaluation of emissions benefits. In fact, the studies generally suggest that emission benefits are somewhat greater than those estimated by the Air Resources Board. These studies are identified and briefly summarized below.

Gasoline Reformulation and Vehicle Technology Effects on Exhaust Emissions. Auto/Oil Air Quality Improvement Research Program, Technical Bulletin Number 17. August 1995.

This test program encompassed three vehicle fleet types with a total of 23 vehicles. The fleets were broken down into older (model years 1983 to 1985), current (model year 1989), and Federal Tier 1 (model year 1994) engine groups. Fuel delivery systems included carbureted, throttle body injected, port fuel injected, and sequential fuel injected. All the vehicles were equipped with catalysts. The program compared cleaner-burning gasoline to a national industry average reference fuel. Exhaust emissions were measured according to standard Federal Test Procedures. Hydrocarbon emissions were reduced by between 12 and 27 percent, carbon monoxide emissions were reduced between 21 and 28 percent, and oxides of nitrogen emissions were reduced 7 to 16 percent. The variation in emission reduction was due to the vehicle group tested; older, current or Federal Tier 1.

Comparison of Exhaust Emissions From California Phase 1 (without Oxygenates) and Phase 2 (Cleaner-Burning Gasoline, with Oxygenates) Fuel: A Case Study of 11 Passenger Vehicles. Society of Automotive Engineers Paper # 961221. May 1996.

The program tested 11 passenger vehicles, each equipped with catalysts. The group included a variety of fuel delivery systems including carbureted, throttle body injected and multi-port fuel injected. Model years of cars ranged from 1979 to 1992. This test program compared California's Phase 1, non-oxygenated gasoline to Phase 2 gasoline (fuel that met the specifications for cleaner-burning gasoline). Each vehicle was tested 60 times under a variety of conditions and driving cycles. Testing was conducted at 50, 75 and

100 degrees Fahrenheit. Ten different driving cycles were tested ranging from a low speed, in town driving cycle to freeway driving cycles encompassing a range of driving speeds. A total of 330 emission test pairs were used to make the findings. The study concluded that the benefits of cleaner-burning gasoline observed over the wide range of driving cycles, including the FTP cycle and those most representative of real-world driving. On average hydrocarbons were reduced 17 percent. Carbon Monoxide was reduced 13 percent and Oxides of Nitrogen was reduced 11 percent.

Dynamometer Study of Off-Cycle Exhaust Emissions. Auto/Oil Air Quality Improvement Research Program, Technical Bulletin Number 19. April 1996.

Eight vehicles were tested using cleaner-burning gasoline in this program. The fleet was divided into 3 different fuel type groups; current gasoline, methanol flexible fuel vehicles, and ethanol flexible fuel vehicles. For all groups exhaust emissions were compared using cleaner-burning gasoline and a national industry average gasoline. The model years of vehicles tested ranged from 1989 to 1993. The test program was designed to study the difference in emissions using a driving cycle which includes higher driving speed, higher acceleration and deceleration (the REP05 driving cycle) compared to the standard test driving cycle (the FTP). The reductions in emissions associated with cleaner-burning gasoline on the FTP cycle were 26 percent for hydrocarbons, 30 percent for carbon monoxide and 18 percent for oxides of nitrogen. Comparing the emissions of vehicles using cleaner-burning gasoline and the industry average gasoline using the off-cycle driving cycle shows a 43 percent reduction in hydrocarbons, a 24 percent reduction in carbon monoxide, and a 21 percent reduction in oxides of nitrogen. The program concluded that the benefits of cleaner-burning gasoline are similar for the FTP and the REP05 driving cycles. It is encouraging that the benefits derived from the use of reformulated gasoline carry over to high-speed, high-load off-cycle emissions as well.

Effects of California Phase 2 RFG on Exhaust Emissions and Vehicle Performance - Quarterly Technical Progress Report. BDM-Oklahoma, Inc. For the Department of Energy. January 1996.

This on-going study of long term effects of fuels on vehicles has a test fleet of five 1994 vehicles with California emissions equipment. These vehicles had 20,000 to 30,000 miles accumulated on them prior to the start of the test. The vehicles then accumulated an additional 30,000 miles of a mix of urban, suburban and highway driving cycles. Emission testing was performed at 2, 10, 20 and 30 thousand miles of operation on the test fuel. The study compared cleaner-burning gasoline to a federal reformulated gasoline and a national industry average fuel. Compared to the industry average fuel, cleaner-burning gasoline showed a reduction in hydrocarbon emissions of 37 percent, a reduction in carbon monoxide emissions of 30 percent, and a reduction of oxides of nitrogen of 8 percent. The study also showed that over the 30 thousand miles, cleaner-burning gasoline did not adversely effect the exhaust emission control systems.

Exhaust Emissions of E85 Ethanol Fuel and Gasoline in Flexible/Variable Fuel Vehicles. Auto/Oil Air Quality Improvement Research Program, Technical Bulletin Number 16. July 1995.

Three flexible fuel vehicles were tested in this program which compared a national industry average fuel to cleaner-burning gasoline and to E85. E85 is a 85 percent blend of ethanol and 15 percent gasoline. The vehicles, designed to run on flexible fuels were equipped with either sequential port injection or port fuel injection fuel delivery systems. The model years ranged from 1992 to 1994. Exhaust emissions were measured by standard Federal Test Procedures (FTP). The comparison of the industry average fuel and cleaner-burning gasoline showed a reduction in hydrocarbon emissions of 24 percent, a reduction in carbon monoxide emissions of 31 percent and a reduction in oxides of nitrogen emissions of 20 percent.

The table below summarizes the results from these studies.

Summary of Exhaust Emission Studies
Cleaner-Burning Gasoline

Study	No. of Vehicles	Model Years	HC Reductions	CO Reductions	NOx Reductions
Gasoline Reformulation and Vehicle Technology Effects on Exhaust Emissions. August 1995	23	1985-1994	12-27%	21-28%	7-16%
Comparison of Exhaust Emissions from California Phase 1 and Phase 2 Fuel: A Case Study of 11 Passenger Vehicles. May 1996	11	1979-1992	17%	13%	11%
Dynamometer Study of Off-Cycle Exhaust Emissions - FTP Results. April 1996	8	1989-1993	26% -FTP 43% - REPO5	30% - FTP 24% - REPO5%	18% - FTP 21% - REPO5
Effects of California Phase 2 RFG on Exhaust Emissions and Vehicle Performance - Quarterly Technical Progress Report. January 1996	5	1994	37%	30%	8%
Exhaust Emissions of E85 Ethanol Fuel and Gasoline in Flexible/Variable Fuel Vehicles. July 1995	3	1992-1994	24%	31%	20%

Summary of Emission Test Studies Used
in Developing the Working Database

Study Title	Fuel Properties Examined	Number of Tests
1. USEPA - Emission Factors	oxygenates	1512
2. Auto/Oil - Program AMOT	aromatic hydrocarbons, olefiins, T90 distillation temperature, oxygenate	1660
3. Auto/Oil - Sulfur-Phase I	sulfur	300

4. Auto/Oil - Sulfur-Phase II	sulfur	224
5. Auto/Oil - Low Sulfur	sulfur	109
6. Auto/Oil - RVP/Oxygenates	RVP, oxygenates, (MTBE, ETBE, ethanol)	471
7. Auto/Oil - MTBE & TAME	MTBE, TAME	80
8. Auto/Oil - T90/Heavy Hydrocarbons	aromatics and T90 distillation temperature	617
9. GM/WSPA/CARB - Driveability	RVP, T90 driveability index, oxygenates	234
10. API - RVP/Oxygenate Program	RVP, oxygenates	154
11. API - Aromatic Hydrocarbons	RVP, aromatic, sulfur, T50, T90	212
12. Chevron - Distillation	T10, T50, T90 distillation temperatures, aromatic hydrocarbons, RVP	449
13. Unocal - RFG	T10, T50, T90 distillation temperatures, aromatic hydrocarbons, RVP, fuel octane, olefins, oxygenates, paraffins	744
14. NIPER - Benzene Precursor Study	benzene, aromatic hydrocarbons	90
15. CARB/ATL - Oxygenate	oxygen, oxygenates, RVP	257
16. ARCO - ECX	sulfur, T50 & T90 distillation temperatures, aromatic hydrocarbons, benzene, olefins, RVP, oxygenates	138
17. ARCO - T50/T90	T50 & T90 distillation temperatures	73
18. Auto/Oil - Methanol	Methanol	39
19. EPA/ATL - Phase I/II	RVP, oxygenates, T90 distillation	

	temperatures, sulfur	278
20. ARB/GM - Confirmation	sulfur, T50 & T90 distillation temperatures, aromatic hydrocarbons, benzene, olefins, RVP, oxygenates	3
	Total	7724