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Technology of
Emission Control
Since the 1960s**

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Cleaner Cars:

The History and Technology of Emission Control Since the 1960s

J. Robert Mondt

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Foreword

This book is an historical overview of the evolution of emission controls for automobiles. It is written from my perspective as a participant in the research and development program at General Motors, where I worked for 43 years. As a mechanical engineer, my technical specialties include thermodynamics, heat transfer, and fluid mechanics. My hands-on experience has been in integrating components into complete vehicle systems, with a particular emphasis on introducing the catalytic converter as a primary component for controlling exhaust emissions from automobiles.

I witnessed the evolution of emission controls starting with the environmental concerns in California in the 1950s, and the crusade to eliminate smog. This movement persisted and gained momentum until, finally, the entire auto industry was involved in meeting emission regulations. The conflict and compassion between lawmakers and the auto industry was fascinating to me. Both realized that clean air was important, and both have worked diligently in their specific arenas to achieve improved air quality.

During the past 30 years, somewhat as a hobby, I have accumulated many references, articles, press releases, and stories about the government agencies, scientists, educators, auto industry executives, and auto engineers who appeared as this fascinating drama unfolded. And in my job at General Motors, I was intimately involved in this drama. As more and more organizations in the auto industry, and especially GM, became involved, I was asked to document the historical developments so that we would have available some educational materials for newly hired individuals who were about to become involved in auto emission controls. This was necessary because at the time there was no publication covering the subject overall, particularly none which presented a comparison of vehicle systems as they evolved.

In 1982, I wrote a tutorial called, "An Historical Overview of Emission-Control Techniques for Spark-Ignition Engines."* This proved to be very popular both within GM and outside. Within GM, it was the basis for a training course that was presented more than 20 times. It was also the basis

* Mondt, J.R., "An Historical Overview of Emission-Control Techniques for Spark-Ignition Engines," GMR Research Publication 4228, General Motors Research Laboratories, Warren MI, 1982.

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for lectures to graduate mechanical engineering students at Stanford and Michigan State for 12 consecutive years, and was published by ASME in 1989 as part of a book entitled "History of the Internal Combustion Engine." Much of this tutorial is also incorporated into the book you now hold in your hands.

The information contained in this book is true and accurate to the best of my knowledge. Any opinions expressed are wholly my own. My perspective is necessarily formed by my role at General Motors; however, to make the viewpoint as general as possible, I have included information provided by other car companies, and I acknowledge the many contributions of individuals outside of General Motors to the development of emission-control technology.

J.R. Mondt

Preface

This book documents the truly amazing story of how we as a nation, over a period of 35 years, succeeded in controlling air pollution from passenger cars. It is dedicated to the hundreds of engineers, scientists, technicians, mechanics, chemists, physical chemists, materials suppliers, university researchers, legislators, and other individuals who contributed to this success story.

The people of the United States should be proud of the U.S. auto industry, manufacturers, and suppliers alike, for the high degree of success they have achieved in controlling air pollution from vehicles. By virtue of a democratic system that permits citizens to voice concerns and motivate government officials to act, industries given the freedom to innovate to find solutions to problems, and an educational system that produces dedicated, hard-working engineers, scientists, technicians, and assembly workers, the air pollution from automobiles as of the year 2000 will have been lowered to minuscule levels compared with those of the late 1960s. Between the years 1965 and 2001, allowable air pollution from passenger cars has been lowered steadily to levels less than 5% of those for pre-control era vehicles; and, at the same time, fleet miles per gallon have more than doubled.

Although the story that follows is one of dramatic progress, now is not the time to rest on our laurels; we must continue to work together to control emissions from automobiles and to ensure a healthy environment for future generations.

Acknowledgments

Many thanks to the following individuals for their contributions to this book and to the field of emission control technology:

Dan Wendland, of GM Research and Development, for editing much of the text, and for most of the technology on converter pressure loss, especially techniques for treating flow maldistribution in the substrate, and for correlating pressure drops for components in the exhaust system. The industry is indebted to Dan for his work in this area.

Kathy Taylor, also of GM Research, who contributed much to catalyst sections.

Harold Haskew, of GM Proving Grounds, who reviewed sections of the text related to vehicle testing and certification, including testing of vehicles in customers use.

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Introduction

Advances in mankind's standard of living over the last century can be characterized in large part by both increased consumption of energy and depletion of energy sources, predominately oil and coal. A byproduct of this process has been a significant increase in the amount of waste matter generated, both on the ground and in the atmosphere. Until recent times, ongoing natural chemical processes have been sufficient to cleanse the environment of most of the pollution and waste materials that have resulted from energy production and consumption. However, in light of a constantly increasing population worldwide and the resultant use of more and more energy-consuming appliances and vehicles, the eradication of these wastes can no longer be left to Mother Nature alone.

At the beginning of the twentieth century, most pollutants still originated from natural sources. However, as early as the 1930s, "smog," originally believed to be a combination of smoke and fog, was present in the Southern California Basin. In other forested regions of the United States, contaminated air resulted in mountain ranges being given such names as the "Blue" or "Smoky" mountains; the chemical forces that produced the colored haze resulted from the reactions of volatile organic compounds (VOCs)—mostly hydrocarbons—and biogenic oxides of nitrogen (NO_x).

By the 1950s, man's contributions to environmental pollution began to increase at an alarming rate, especially in energy-consuming nations such as the United States. At mid-century, major sources of air pollution included human and animal waste, effluents from manufacturing plants and power generating plants, and, increasingly, exhaust from automobiles.

During the prosperous 1960s, the automobile became synonymous with the free-wheeling nature of life and culture in the United States. A prosperous household wanted and could afford to have at least two cars. And the vast freeway system initiated during the Eisenhower Administration made transportation by car convenient and inexpensive, enabling motorists to visit every corner of the United States as well as venture into Canada and Mexico. The U.S. automobile industry could do no wrong! More and more cars were manufactured to satisfy every customer need. New styles of vehicles were produced, including larger models of station wagons, sports cars, and small

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trucks. Customers responded readily to each advance in comfort and convenience, which included air conditioning, power brakes, power steering, electric windows, and electric door locks. However, the downside was that all of these developments increased the per-vehicle energy consumption.

In the decade of the 1960s, approximately 20% of the energy consumed in the United States could be attributed to automobiles. Essentially all passenger vehicles were powered by hydrocarbon-based fuel, mostly gasoline. As the total automotive fleet expanded rapidly in the 1940s and 1950s, vehicles came under severe attack as air “polluters,” especially in California. Exhaust emissions from automobiles increasingly were identified as a significant contributor to air pollution. Professor Phillip Myers of the University of Wisconsin stated, in 1966, that “air pollution is a problem to be concerned with—we automotive engineers have a special interest and contributions to make since automobiles produce about 60% of the total mass of air pollutants” [11.1].

The engineering and technical communities were challenged to become “good neighbors” of the environment by finding ways to reduce automotive emissions and thereby help to improve air quality. As is frequently the case with social and technological change, the initiative for action started in America’s most populous western state, California.

Reference

- 11.1 Myers, P.S. “Automobile Emissions—A Study in Environmental Benefits Versus Technological Costs,” SAE Paper No. 700182, Society of Automotive Engineers, Warrendale, Pa., 1970.

"ODE"(r) of Pollution

The following poem was written by Ernest W. Landen from Caterpillar Tractor Co. and was printed in the April 1968 issue of the *SAE Journal*. The poem captures the essence of the historical efforts to control pollutants and emissions:

In recent years men of scientific mind
Have been diligently trying to find
A simple and unequivocal solution
To a problem known as air pollution

In years gone by when streets were mud
Enriched with animal droppings and other crud
Debate ensued, mixed with indecent talk
Until villages installed the first sidewalk

But still when people crossed the street
The tenacious muck stuck to their feet,
The fair sex naturally with distaste of grime
Demanded ways to escape this slime.

Some townsmen said with great remorse
We must get rid of the nasty horse,
While others thought dignity could be saved
By simply having the whole street paved!

Thus emissions were limited to discrete piles
Around which people walked with smiles
And busy tumble bugs enjoyed their day
Until the cleaner swept it away.

The people now had settled down
To enjoy the pure fresh air of town
Until the experiments of Professor Otto
Produces a vehicle called the auto.

This faster mode of transportation
Quickly reduced the equestrian population
Where once a single span of horses stood
A hundred now hid beneath the hood.

Where clip clop of horses once filled the street
The roar of tailpipes now set the beat
Autos, taxis, trucks and the bus
All clutter the street in front of us
The products of combustion now of course
Differ completely from those of the horse