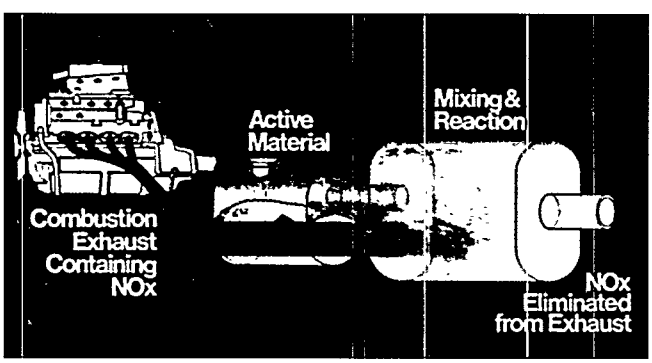
in the failure of designers and developers to exploit potential efficiency improvements in combustion systems and devices. For more than 20 years, the quench-layer theory dominated the technical literature as the model for unburned hydrocarbon emissions from automotive engines. Today, a new understanding of the sources of unburned hydrocarbon emissions from dilute homogeneous-charge engines has developed from the collective efforts of eight industry and DOE-contractor research teams.

The researchers have completed the experiments and analyses to prove conclusively that conventional wisdom was incomplete regarding the origin of unburned hydrocarbon emissions in piston engines. The process of flame quenching by the cold walls, which had been previously thought to be the main cause of unburned hydrocarbon emissions from dilute homogeneous-charge engines, has now been determined to be of negligible importance. It is now understood that piston ring and head-gasket crevice volumes and the absorption/desorption by lubricating oil filters and combustion chamber deposits are largely the controlling factors.

This new understanding of the physical processes allows engine designers to focus their efforts on the difficult engineering tasks of reducing these crevice volumes and solving the continuing problems in warm-up and transient operation. These efforts should lead to the resolution of a major technical limitation in use of this engine concept.

RAPRENO$_X$ Process

Nitrogen oxides are the leading contributors to air pollution today. In fact, more than 21 million tons of nitrogen oxides are released into the atmosphere in the United States each year as a by-product of burning fossil fuels. DOE has sponsored research to combat this problem. As a result of this work, Sandia National Laboratories announced in 1986 the discovery of a new process called RAPRENO$_X$ (rapid reduction of nitrogen oxides), which could eliminate nitrogen oxides from diesel engine exhausts and coal-burning generating plants.



The RAPRENO$_X$ process can eliminate nitrogen oxides from the exhaust streams of diesel engines and coal-burning generating plants.

The first phase of the research, funded by the DOE Office of Basic Energy Sciences, included a series of experiments that determined the basic chemistry of the process. Later, with funding from the Office of Conservation and Renewable Energy, scientists extended the fundamental chemistry research by applying the process to the exhaust gases of a real diesel engine. In these applied experiments, it was shown that RAPRENO$_X$ could reduce 400 parts per million of nitrogen oxides to less than 5 parts per million in diesel exhaust at characteristic operating temperatures.

The RAPRENO$_X$ process can significantly reduce nitrogen oxide emissions from practical combustion systems, including stationary and mobile diesel engines, industrial scale furnaces and boilers, and other fossil-fired generating systems. In fact, the successful development of the process could provide an inexpensive way for industry and utility companies to comply with mandated Federal clean air standards.

DOE waived patent rights to the inventor, who consequently formed a private company, the Technor Corporation, to commercialize RAPRENO$_X$ for use in diesel engines, natural gas-fired engines, and wood-fired boilers. Technor just completed a feasibility study to determine the applicability of the RAPRENO$_X$ process for coal combustion. In addition, major engine manufacturers, electric utility companies, air quality interests, and industrial processors in the United States and abroad have shown widespread interest in the process, and many have begun R&D activities.

Thermal-Boundary-Layer Measurements in Engines

Despite the importance of the thermal boundary layer in understanding engine combustion processes, the temperature profile has never been measured quantitatively near a wall in an operating internal combustion engine. In most engine combustion heat-release