computations, the thermal boundary layer is calculated theoretically because direct measurements are not possible. Because nitric oxide emissions from an engine chamber are highly sensitive to peak temperatures in the chamber, it is important that these temperatures be calculated correctly with an accurate model of the thermal boundary layer.

With DOE funding, researchers were able to acquire the first detailed in-cylinder measurements of the thermal boundary layer evolution in an operating internal combustion engine. These techniques demonstrated excellent spatial resolution of more than 0.08 millimeter and were able to traverse to within 0.05 millimeter of the wall. Profiles were generated several times during the expansion stroke, showing the growth of the layer from fractions of a millimeter to nearly 2 millimeters.

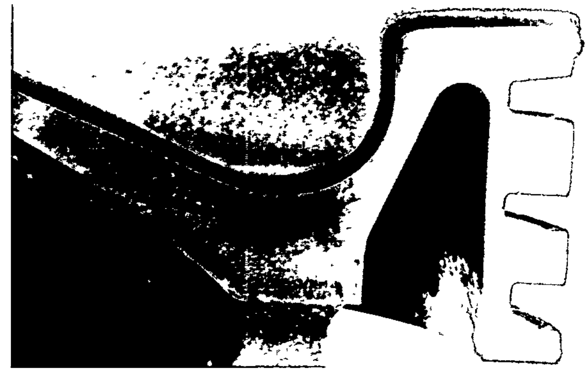
These measurements are a necessary first step in developing a complete picture of the combustion/wall interactions. Combined with wall heat-transfer measurements being performed collaboratively with researchers from the General Motors Research Laboratory, the fundamental knowledge developed should lead to new engine designs that simultaneously optimize emissions control and fuel efficiency.

Thermal-Barrier Coatings

The fuel economy and emissions performance of diesel engines need to be improved. DOE is addressing this need through its Heavy Duty Transport Technology Program. The program supports research to develop a technology base applicable to advanced, high-temperature diesel engines.

One area of particular interest to DOE is the development of thick, thermal-barrier coatings to achieve effective insulation of the combustion chamber. When used in diesel truck engines, thermal-barrier coatings improve fuel economy, increase engine power density, and reduce parasitic losses.

To date, several applications of thermal-barrier coatings have emerged from DOE-supported work. For example, the first diesel engine piston to incorporate thermal-barrier coatings was recently designed. The piston uses a thick thermal-barrier coating (zirconia ceramic) on the crown surface. The plasma-sprayed zirconia ceramic coatings, processes, and equipment developed in DOE's Heavy Duty Transport Program



Thermal barrier coatings for diesel engines improve fuel economy, increase engine power density, and reduce parasitic losses.

also led to the development of a coating for marine and stationary engines. In these applications, the coating is used to protect against corrosion and to extend valve life.

Transformation-toughened Ceramics Data Base

Transformation-toughened ceramics, such as partially stabilized zirconia, tetragonal zirconia polytypes, and zirconia-toughened alumina, offer important options for advanced engines because of their high strength and toughness, high coefficient of thermal expansion (similar to that of cast iron), and good thermal insulation properties. Yet ceramics are highly complex materials, and early experiments found that their performance in engines was unpredictable. Under the Advanced Materials Development Program, researchers developed a comprehensive data base of the mechanical and physical properties of ceramics as a function of time, temperature, stress, relative humidity, and thermal history.

The data base of properties now contains results of 3924 tests for 23 properties of 282 different batches of ceramic materials. Approximately one-half of these are zirconia-based ceramics; the other half includes silicon carbides, silicon nitrides, whisker-reinforced silicon nitrides, and alumina-based (including whisker-reinforced) materials and mullites. The data from this research were compiled in a computerized data base and released to industry. The information helps designers develop advanced engines for commercialization.