Abstracts

Laboratory Capabilities

WORKING WITH THE U.S. DEPARTMENT OF ENERGY NATIONAL LABORATORIES

The U.S. Department of Energy (DOE) national laboratories have many types of contractual research and development (R&D) agreements to meet the needs and interests of industry. The following are brief descriptions of the types of agreements most commonly used. For more information on working with a specific laboratory, please call the individual contacts below.

COST-SHARED R&D

Cost-shared R&D is usually conducted under a cooperative research and development agreement (CRADA). Both the partnering organization and the laboratory contribute to the costs of the R&D and share the results. The industry partner may obtain exclusive rights (in a field of use) to inventions created by the laboratory. The results of the CRADA work can be protected from disclosure for a period of up to 5 years after completion of the work.

REIMBURSABLE R&D

"Work for Others" (WFO) is R&D, or technical services, where costs are paid entirely by the sponsoring organization or company, and the work is conducted by the laboratory. Under certain conditions, the company may take title to inventions created by the laboratory under the WFO. Research results are considered proprietary if so designated by the company.

LICENSING

Opportunities to acquire rights in laboratory inventions and copyrights are available. Licenses may be nonexclusive, depending on the nature of the intellectual property and the business fields to be actively pursued by the licensee.

PERSONNEL EXCHANGES

Industry researchers can work at a laboratory site, or vice versa, on research of mutual interest. Each party pays for the cost of its own employees. Appointments range from 3 months to 1 year.

TECHNICAL ASSISTANCE

Laboratory researchers provide short-term technical assistance to companies with technical problems requiring expertise that is not available commercially. Funding arrangements vary.

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LAB CAPABILITY MATRIX

Technology Area	ANL	INEEL	LLNL	NREL	ORNL	PNNL	Sandia
Fuels and Lubricants							
Advanced Petroleum-Based Fuels	X	X	X	X	X		X
Alternative Fuels	X	X	X	X	X	X	X
Lubricants (synthetic and petroleum-based)	X			X			
Reduced friction	X		X		X		
Vehicle Systems							
Aerodynamics			X			X	X
Rolling resistance		X	X		X		
Auxiliary systems			X			X	
Heavy hybrids	X	X	X	X	X		
Friction and wear	X				X		
Thermal management	X				X	X	X
Systems modeling and analysis	X	X	X	X	X	X	X
Engines							
Combustion and emissions control modeling	X		X		X	X	X
Light-truck engines	X	X	X		X	X	X
Heavy-truck engines	X	X			X	X	X
Waste heat utilization	X					X	
Lightweight moving parts		X			X	X	
Lightweight engine blocks	X	X			X	X	
Emissions reduction technology	X		X	X	X	X	X
Materials							
High-strength weight reduction	X	X	X		X	X	X
Coatings	X		X		X	X	X
Propulsion system materials		X			X	X	X
Environment and Health							
Emissions Testing	X	X		X	X	X	
Environmental and health impacts	X	X	X			X	
Truck Safety							
Brakes		X			X	X	
Fuel Storage	X	X		X	X	X	
Crash-energy management	X		X		X	X	
Ergonomics		X			X		

ARGONNE NATIONAL LABORATORY

Argonne National Laboratory, one of the U.S. Government's largest research and development laboratories, is committed to research and development leading to high-quality, cost-effective products that meet the Nation's goals for improving energy efficiency and reducing emissions, as well as the transportation industry's goal of manufacturing affordable advanced-technology vehicles.

Argonne's location, in the heart of the Nation's automotive, truck, and engine (gasoline and diesel) manufacturing industry, facilitates frequent, personal, and cost-effective interaction between Argonne researchers and industry representatives. Argonne is easily reached from Chicago's two major airports, O'Hare and Midway.

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CAPABILITIES

Engine Research

Argonne's engine research facilities, skilled staff with extensive industry engine manufacturing experience, and associated engine/vehicle modeling expertise are combined to conduct a wide range of engine experiments and to develop new technologies to improve engine performance, increase fuel economy, and reduce emissions. Argonne has developed novel approaches:

- to improve fuel economy and power density
- to reduce exhaust emissions
  - particulates and smoke in diesel engines
  - carbon monoxide, hydrocarbons, air toxics, and aldehydes in gasoline engines
  - two new patents for nitrogen oxide control (in-cylinder and aftertreatment)
- to use low-grade and non-petroleum fuels

Sensors

Scientists at Argonne are researching an array of rugged, low-cost sensors that record vehicle information instantaneously, so that engine and drivetrain components can be activated or adjusted in response. The result will be constant, seamless adaptation of system components to each other as the vehicle travels, delivering better mileage and fewer emissions.

Argonne-developed near-frictionless carbon coating is produced in a high-vacuum chamber.

Friction and Wear/Lubricants

Argonne is developing advanced friction, wear, and lubrication tech-nologies to improve the reliability and durability of critical engine components deleteriously impacted by low-emission fuels and lubricants and exhaust gas recirculation strategies required to improve engine emissions.

Thermal Management

Argonne researchers are working on improved thermal-management systems that include compact heat exchangers, innovative heat-transfer schemes, and environmentally friendly "nanofluids" with improved heat-transfer properties.

Supercomputing Applications

As a member of the U.S. Car Council on Automotive Research Supercomputer Automotive Applications Partnership (SCAAP), Argonne is helping to bring advanced modeling and massively parallel supercomputing to automotive design engineers. SCAAP's efforts have focused on the development of computer codes that enable massively parallel superconducting to be used in vehicle design: one code "crash-tests" composite frame components without damaging real cars, the other models airflow inside the vehicle passenger compartment. Recent work has included development of new models to calculate and predict underhood thermal management conditions in both conventional and hybrid vehicles.

Technology Assessment

Argonne has developed comprehensive analysis techniques that provide definitive projections of the effects of using advanced transportation technologies and of the Government policies that may stimulate their development and use. Staff members combine expertise in civil and mechanical engineering, economics, environmental science, and transportation planning to perform large-scale, comprehensive assessments of the interactions among engineering, economics, and the environment.

Nondestructive Characterization of Materials

As part of U.S. Department of Energy's (DOE) Office of FreedomCAR and Vehicle Technologies research, Argonne scientists are developing methods for nondestructive characterization of materials in cooperation with two major engine manufactures. Argonne is working on valve trains, insulating materials, and the fuel delivery system.

UNIQUE FACILITIES/EQUIPMENT/CAPABILITIES

Novel Approaches to Emissions Control

In 1999 Argonne's method for controlling diesel and gasoline emissions by selectively modifying intake air received an R&D 100 Award. The technique used a "chemical filter" membrane that separates air into oxygen- and nitrogen-rich streams for use in the engine. Engines using this technology have the potential to meet the U.S. Environmental Projection Agency's NO_x and particulate emissions standards for locomotives, trucks, and cars for the year 2004.

Evaluating Hybrid Vehicles

Argonne's hybrid electric vehicle (HEV) systems activities include modeling using the Powertrain Systems Analysis Toolkit (PSAT), prototyping (PSAT-PRO), and testing at the Advanced Powertrain Test Facility. PSAT modeling simulates over 100 drivetrain configurations; fuel consumption and exhaust emissions for 15 different cycles; performance; and powertrain transient phases. Argonne's hybrid testing experience includes over 100 HEV's (comprising about 70 different hybrid configurations) in DOE-sponsored competitions, extensive Toyota Prius and Honda Insight testing, and the development of HEV procedures and instrumentation.

Advanced Powertrain Research Facility

State-of-the-art equipment in this integrated facility allows the study of HEV powertrain performance, efficiency, and emissions – without installing components in a vehicle. The flexible facility can also be used to test and develop direct-drive, or stand-alone, engine technologies. Integrated exhaust emissions testing equipment allows testing of both spark-ignition and compression-ignition engines using both conventional and alternative fuels.

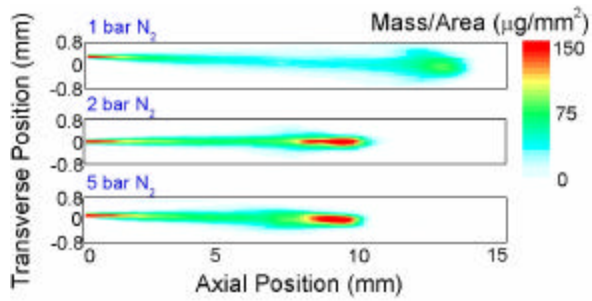
Advanced Powertrain Research Facility

A unique four-wheel chassis dynamometer with top-grade emissions measurement instruments is now operational. This facility is "hydrogen-fuel capable" and can measure emissions from super ultra-low emissions vehicles (SULEV).

Engine Research Facility

At Argonne's Engine Research Facility, researchers are investigating engines ranging in size from automotive through locomotive. This unique world-class facility enables researchers to study high-pressure fuel-injection systems, in-cylinder and aftertreatment of exhaust emissions, and methods to improve power and fuel economy.

Advanced Photon Source



X-ray measurements of Diesel Fuel Sprays

The world's brightest x-ray source, Argonne's Advanced Photon Source (APS), is a unique user facility that is being used to explore the dense core of the fuel spray in the near-nozzle regime where lasers cannot penetrate. Better understanding and control of the fuel spray structure and atomization process are essential for improving engine performance and emissions levels. Argonne researchers, working with the fuel-injector manufacturers, have reported the first quantitative data ever on droplet velocity, local air/fuel ratio, and mass flux from optically dense areas. Argonne researchers were the first to discover the existence of shock waves in diesel fuel sprays. The APS is also being used to probe the chemical bonding and microstructure of near-surface regions of interacting surfaces to understand how lubricant additives behave under high stresses.

Near-Frictionless Carbon Coatings

Ultra-low friction, combined with other unusual mechanical and chemical properties, makes Argonne's near-frictionless carbon (NFC) coatings ideal for many transportation applications. Argonne researchers have determined that NFC aids emissions reduction in compression ignition direct inject engines operating under severe conditions. Investigations are now under way to determine the performance of NFC coatings with engine lubricant additives. NFC coatings should allow oil formulations with low levels of sulfur, phosphorous, and other metallic compounds that poison aftertreatment devices.

Fuel Cell Test Facility

The Fuel Cell Test Facility at Argonne National Laboratory provides an independent resource for testing and evaluating fuel cell stacks and systems up to 50 kW. Through standardized tests and test conditions, Argonne provides its sponsors with comparative data on the performance, operational characteristics, and durability of fuel cells. The test results also help developers and sponsors evaluate technical progress.

Battery Analysis and Diagnostic Laboratory

Argonne's battery laboratory has evaluated more than 4,000 cells and batteries since 1976. It tests 4-Wh cells to 50-kWh batteries and provide versatile test capabilities, which include 120 independent test stations, ability to simulate any driving profile, -75ºC to +200ºC chambers, and up to 500 volts+/-500 amperes. The laboratory has evaluated batteries for DOE, the U.S. Advanced Battery Consortium, and battery developers and users. Advanced cell and battery technologies for both electric vehicle and HEV applications have been tested. A unique four-wheel chassis dynamometer with top-grade emissions measurement instruments is now operational. This facility is "hydrogen-fuel capable" and can measure SULEV emissions.

Rapid Tooling

Argonne researchers are refining a system for rapid tooling of very hard ceramic materials that provides direct, near-net-shape of tools using solid free-form fabrication. The system will help companies inexpensively reduce the time required to go from design to finished part. Specifications can be adjusted and retested before the design is cast into a costly die.

PATENTS AND AWARDS

For its transportation-related research, Argonne National Laboratory has over 200 patents, 11 R&D 100 Awards, 2 Discover Awards, 4 FLC Awards, 2 PNGV Awards, and 2 DOE Awards.

RECENT AND ONGOING EFFORTS

Argonne has forged successful working partnerships with major engine and vehicle manufacturers, as well as with universities recognized for their engine research. These include:

DaimlerChrysler
General Motors Corp.
Ford Motor Company
adapco, Inc.
Caterpillar
Cummins
Delphi
Diesel Technology Company
DuPont
Electro-Motive Division of General Motors
Outboard Marine Corp.
Robert Bosch Corporation
Spawr Industries, Inc.
3M
United Catalysts Corporation
U.S. Advanced Battery Consortium

FOR FURTHER INFORMATION

Visit the Argonne National Laboratory Transportation Technology R&D Center's web site at http://www.transportation.anl.gov.

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CAPABILITIES

Fuels and Lubricants

Alternative Fuels **-** The focus of the Idaho National Engineering and Environmental Laboratory's (INEEL) Alternative Fuels Program is on liquefied natural gas (LNG) and compressed natural gas (CNG) as alternatives to conventional gasoline and diesel fuel for powering heavy and light vehicles within the INEEL fleet. The program continues to convert transit buses, cars, pickup trucks, and vans in the INEEL fleet for operation on LNG or CNG. In addition, the onboard storage capacity of 48 bifuel CNG vehicles is being increased by the addition of second CNG tanks and the use of larger CNG tanks at higher storage and fueling pressures. However, the few replacement vehicles (0.5 percent of the total fleet) being added to the fleet are all ethanol vehicles.

Research is being performed to develop new technologies that strengthen LNG and CNG infrastructures. Projects include a small-scale liquefaction plant, a low-cost refueling station, a cold-tank pressurizing device, and a nozzle standardization effort.

Development is underway at INEEL on processes that produce hydrogen from nuclear, methane, water, biomass, and other abundant sources. INEEL is pursuing development and commercialization of technologies related to production, infrastructure, utilization, and storage of hydrogen and hydrogen/CNG- blended fuels.

INEEL has embarked on a major new lab-wide initiative to support the development and implementation of bioenergy to support the Nation's bioenergy initiative. The focus of the INEEL bioenergy initiative will be "whole crop utilization." Crop residues represent a very significant potential fuel source that is currently greatly underutilized. INEEL brings world-class capabilities in biotechnology, sensors and controls, simulation and modeling, and separations. The laboratory has a long successful history of working collaboratively with industry.

Vehicle Systems

Vehicles - INEEL has over 1,600 vehicles in its fleet. Its trained technicians and mechanics are certified not only to do a variety of specialized tasks but also to do warrantee work on most vehicles. In the heavy-truck category, 150 are truck-type vehicles and 99 are motor coach buses. INEEL is currently using 110 CNG and 50 LNG vehicles (including 7 transit buses) as well as methane, biodiesel, diesel, electric, ethanol, and propane vehicles. (The 7 LNG-equipped transit buses emit 50-percent less nitrous oxide and 98-percent fewer particulates than diesel engines.)

Robotics - The INEEL Robotics and Intelligent Machines department has developed advanced control architectures that support the optimum operation of field equipment. These control architectures range from total autonomous operation of the vehicle with optimal path and decisionmaking capabilities to operator-assisted control, which allows the operator to perform the primary task while the computer monitors and controls secondary tasks. These control architectures have been deployed on actual commercial equipment provided by a heavy-equipment vendor and utilized in field operations. They have demonstrated increased operational capabilities and reduced operator fatigue and training.

Systems Modeling - INEEL is also tasked to develop, extend, refine, and utilize computer models and databases to assist in the assessment of advanced powertrain and battery system concepts and in the interpretation of test data reported to the automobile community. This activity also evaluates and lends meaning to data collected in laboratory and field tests. Dynamometer and battery test data are routinely compared with a simulation model to validate the simulation and to better understand laboratory test results.

Materials

Rapid Tooling and Joining Technology - Nearly all mass-produced items require hollow casts or dies for their formation. Compared to conventional fabrication methods, INEEL-developed rapid-solidification process tooling reduces cost and turn-around time for production of precision tooling by a factor of 5-10. The process involves spraying layers of molten metal onto a three-dimensional pattern and building up the layers into a full-size die. INEEL expertise in joining, casting, and coating technologies encompasses many general areas, including: equipment and processes, automation and mechanization, feedstock materials, manufacturing and processing methods, materials characterization and evaluation, testing and characterization, quality assurance, nondestructive evaluation, applications, and refurbishment.

Environment and Health

Emissions - INEEL has the capability to conduct combustion engine exhaust analysis in accordance with the U.S. Federal Test Procedure. INEEL's exhaust-gas analysis capabilities include the ability to monitor, in real time, up to 25 gaseous species in raw or diluted exhaust via state-of-the-art Fourier Transform Infrared (FTIR) spectroscopy. In addition to the ability to conduct real-time analysis of exhaust emissions provided by the FTIR, the laboratory has acquired an AVL North America, Inc., Constant Volume Sampling bag system. The composition of gases in the bag can then be analyzed using a variety of analytical techniques, including FTIR. A fully equipped analytical laboratory capable of complete gas and particulate analysis for toxic components that impact health and safety supports the emissions capability.

Truck Safety

Human Factors - The Human Factors Engineering discipline at INEEL is the largest among the U.S. Department of Energy (DOE) laboratories and is broadly recognized outside DOE. The core competency in human-machine interaction (including safety, instructional design, and human reliability) is supported through the Center for Human-System Simulation and a cadre of professionals. This center provides enabling knowledge and technologies to support effective designs for current and future systems. INEEL knowledge of the psychology and biology of humans and organizations is leveraged to produce designs that are more efficient and significantly safer than existing systems. A core competency in human reliability has been long established at INEEL, and INEEL is recognized as a world leader in the area.

UNIQUE FACILITIES AND EQUIPMENT

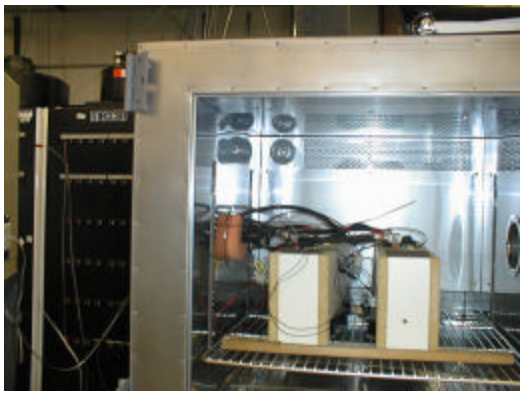
Transportation Center

The INEEL Transportation Center is large enough and suffi-ciently to handle almost any heavy vehicle integration, demonstration, or verification project. The Transpor-tation Center bays are specially designed to handle difficult fuel, engine, battery, or fuel-cell issues with sever-al air exchanges per hour and the necessary lifts and hoists to accom-modate all equipment needs. The center is equipped with a 500-hp engine dynamometer that can sim-ulate driving cycles and is equipped with state-of-the-art emission (inclu-ding particulate) characterization equipment.

Transportation Center capabilities exist to support complex engine or vehicle modifications and conversions, vehicle instrumentation and testing, complex data analysis, cooling and exhaust system modeling/testing, and large systems engineering/integration programs. The Center is supported by well-equipped analytical and research laboratories staffed by scientists and engineers from most technical disciplines. INEEL also possesses considerable economic analysis expertise that is capable of evaluating energy and life-cycle costs on components, vehicles, and transportation systems.

Energy Storage Technologies Laboratory

The Energy Storage Technologies Laboratory at INEEL is the world leader in the testing of advanced battery technologies and ultracapacitors. It is the only national laboratory to document measurement uncertainty procedures for data quality, and it has pioneered the development of analysis procedures for battery scaling, thermal management, capacity fade, and power fade. The Energy Storage Technologies Laboratory offers controlled testing on batteries, fuel cells, ultra-capacitors, and mechanical flywheels under conditions typical of electric and hybrid vehicle applications. Tests can be performed on small storage components as well as large multi-component heavy-vehicle storage systems. The Energy Storage Technologies Laboratory is the lead DOE facility for hybrid vehicle battery performance and life-characterization studies.



RECENT AND ONGOING EFFORTS

Diesel Truck Idle Reduction Demonstration Project

The INEEL is conducting a heavy-truck idle-reduction demonstration project to support the reduction of the 800+ million gallons of diesel fuel annually used during idling periods, such as when loading and unloading loads or when the drivers rest. The project activities include assessing regional and national driver/truck idling needs and practices. Various idling technology options for heating, air-conditioning, and auxiliary loads are being demonstrated with the objective of matching driver and mission needs and technology capabilities. The activities include several fleet and component demonstrations, a data-collection effort, and the analysis and dissemination of the demonstration results.

Oil Bypass Filter Technology Evaluation

The objective of the oil bypass filter evaluation is to demonstrate and quantify engine-oil use reductions possible from oil-bypass filtration systems. Oil-bypass filter systems are currently installed on eight INEEL motor coach diesel buses. The eight buses have accumulated 200,000 evaluation test miles. Additional systems are being installed on six Chevrolet Tahoes. The oil is regularly sampled for 26 additives and contaminants. The evaluation project will include an economic benefits analysis for each vehicle and for the INEEL fleet as a whole. If the demonstration is successful, the analysis will be expanded to identify DOE complex-wide economic and oil reduction benefits.

Advanced Vehicle Testing Activity

The Advanced Vehicle Testing Activity (AVTA) is a DOE activity managed by INEEL that tests advanced technology vehicles and the infrastructure necessary to support the vehicles. In conjunction with private sector testing partners, Electric Transportation Applications and Arizona Public Service, the testing has included the construction and operations of a hydrogen production and fueling pilot plant. The hydrogen, which is produced by operating a PEM fuel cell in reverse, supports the testing of 20 internal combustion engine vehicles operating on 100-percent hydrogen and blends of hydrogen and CNG fuels. The hydrogen vehicles have accumulated 200,000 test miles while

operating on hydrogen and hydrogen/CNG-blended fuels. The AVTA is currently testing 16 hybrid electric vehicles; 750,000 miles of maintenance, operations, and fuel economy data have been accumulated on the hybrid-electric vehicles. An additional 400 neighborhood and urban-electric vehicles are also in testing.

INEEL continues to work with heavy-duty diesel engine manufacturer Detroit Diesel to explore concepts of LNG application in the INEEL bus fleet. A cooperative research and development agreement (CRADA) signed with Detroit Diesel in 1995 remains active today. This CRADA has resulted in the conversion of seven diesel buses to LNG and has aided this industry partner in commercializing natural gas technology. INEEL has also performed a 750-hour heavy-duty engine durability test and provided engineering and technical support for Westport Innovations, a Canadian engineering company.

FOR FURTHER INFORMATION

http://www.inel.gov
http://energy.inel.gov/eenr/default.shtml
http://avt.inel.gov

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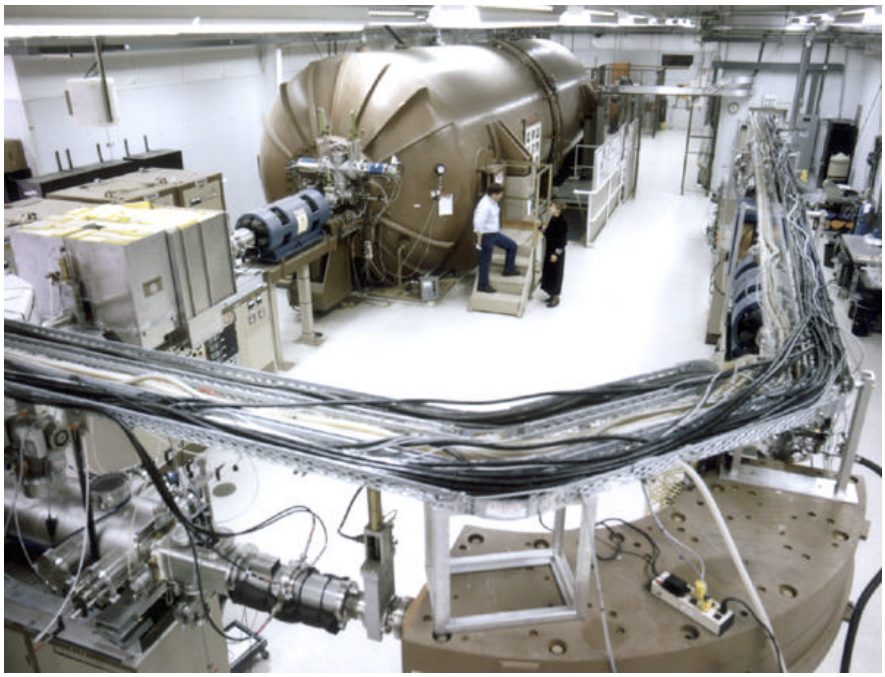
CAPABILITIES

Fuels and Lubricants

Chemical Kinetics **--** The kinetic modeling effort at Lawrence Livermore National Laboratory (LLNL) is a world-class capability focused on developing detailed chemistry mechanisms for fuel decomposition, ignition, and combustion under homogeneous charge compression ignition (HCCI) and diesel engine conditions for various fuel types, including gasoline, diesel, and alternative fuels. This effort also consists of the development of appropriate fuel surrogates for real distillate fuels that are computationally tractable. Understanding the detailed kinetics is central to predicting compression ignition combustion and the selection of appropriate fuels. Once developed, the kinetic mechanisms are made available to industry and other researchers for application in a variety of engine-simulation models. westbrook1@llnl.gov

Isotopic Tracing of Fuel Components in Engine Emissions Using Accelerator Mass Spectrometry (AMS) -- LLNL is the site of the Center for Accelerated Mass Spectrometry (CAMS). This is the most versatile, precise, and productive AMS facility in the world. We are applying this facility as a unique diagnostic tool for conducting detailed analysis of engine combustion. CAMS allow us to determine exact concentrations of carbon isotopes (^{12}C and ^{14}C) in a gas stream or in solid particles. This capability makes it possible to conduct engine diagnostic experiments that were never before possible. A recent example is determining what fraction of particulate matter (PM) engine emissions originates in the fuel or in the lubricant. This is done by running an engine with a fuel with contemporary concentration of ^{14}C (a renewable fuel) and

with a fossil-based lubricant (which contains no ^{14}C isotopes). Under these conditions, any ^{14}C in the PM is known to originate in the fuel, allowing an accurate calculation of the origin of PM emissions. Other applications include detailed validation of chemical kinetic mechanisms and evaluation of oxygenated fuels for diesel engines. bbuchholz@llnl.gov



CAMS facility at LLNL

Fuel and Additive Risk Assessment **--** The Consortium for Fuels Assessment (CFA) is a systems-based framework to prepare scientifically sound assessments of the potential health and environmental impacts of fuel compounds necessary to meet future emissions standards. We use a combination of analytical and experimental techniques to determine the environmental impact of additives used for fuels, lubricants, or aftertreatment systems. The goal is to detect and avoid future MTBE-like problems before they happen.

The CFA has completed a major assessment for the California Environmental Protection Agency on the consequences of using ethanol as a gasoline oxygenate. We also conducted an analysis of the environmental chemistry of alkylates, which are high-octane components in gasoline. Future plans focus on selection and analysis of optimum fuels for new combustion regimes (HCCI, smokeless rich combustion, modulated kinetics [MK], etc.). layton1@llnl.gov

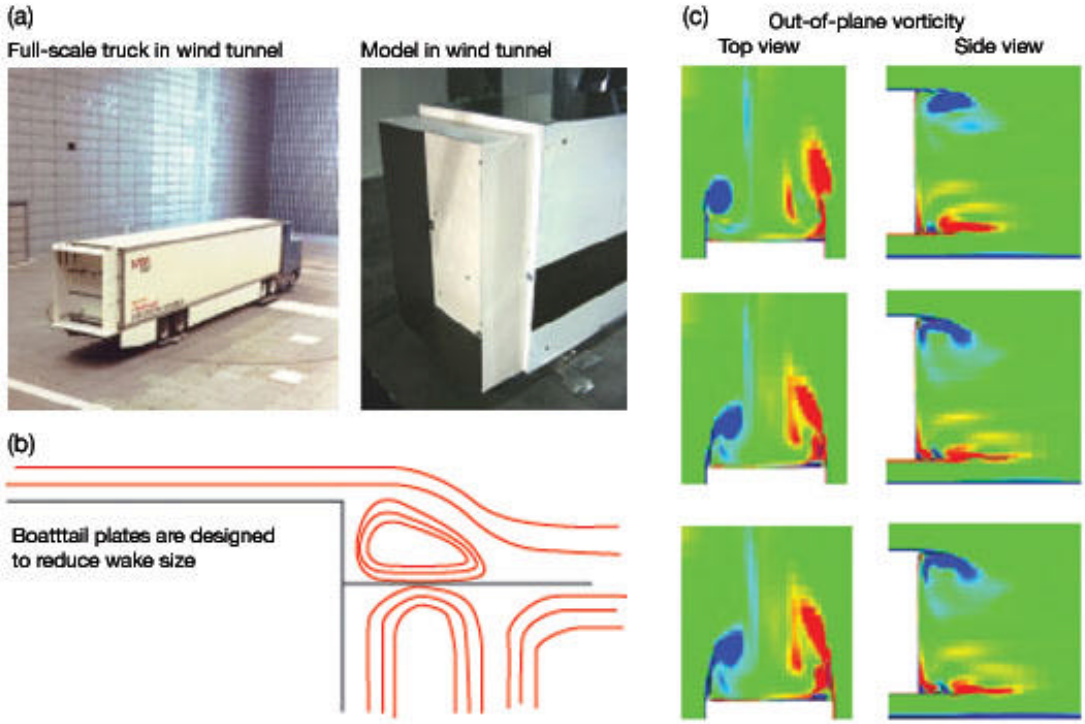
Vehicle Systems

Vehicle Aerodynamics **--** LLNL is leading a consortium effort with representatives from U.S. Department of Energy (DOE) national laboratories, the National Aeronautics and Space Administration (NASA), and universities to reduce fuel consumption on heavy vehicles by reducing the aerodynamic drag. Today, a heavy vehicle (Class-8 truck) traveling at 70 miles per

hour requires 65 percent of its engine output to overcome the aerodynamic drag. It is conceivable that present-day truck drag coefficients can be reduced by as much as 50 percent. The drag reduction can be achieved through altering the truck shape, integrating the tractor and the trailer, and add-on devices. DOE encourages industry participation and involvement in the consortium from both tractor and trailer manufacturers and fleet operators.

The goal of this effort is to develop and demonstrate the ability to simulate and analyze aerodynamic flow around heavy vehicles using existing and advanced computational fluid dynamics (CFD) tools. Activities include an extensive experimental effort and the development and demonstration of new concepts and technologies for aerodynamic drag-reducing devices. The final products are an experimental database, validated CFD methods, and add-on devices to reduce aerodynamic drag of heavy vehicles and thus improve their fuel efficiency and reduce emissions.

Experiments on models of generic and integrated tractor-trailers are underway at NASA Ames Research Center in Moffett Field, California; the University of Southern California (USC) in Los Angeles, California; and Georgia Tech Research Institute (GTRI), in Atlanta, Georgia. Companion computer simulations are being performed by LLNL in Livermore, California; Sandia National Laboratories (SNL) in Albuquerque, New Mexico; California Institute of Technology (Caltech) in Pasadena, California; and Argonne National Laboratory (ANL), in Argonne, Illinois. USC, LLNL, and GTRI are developing devices for reducing aerodynamic base drag. salari1@llnl.gov



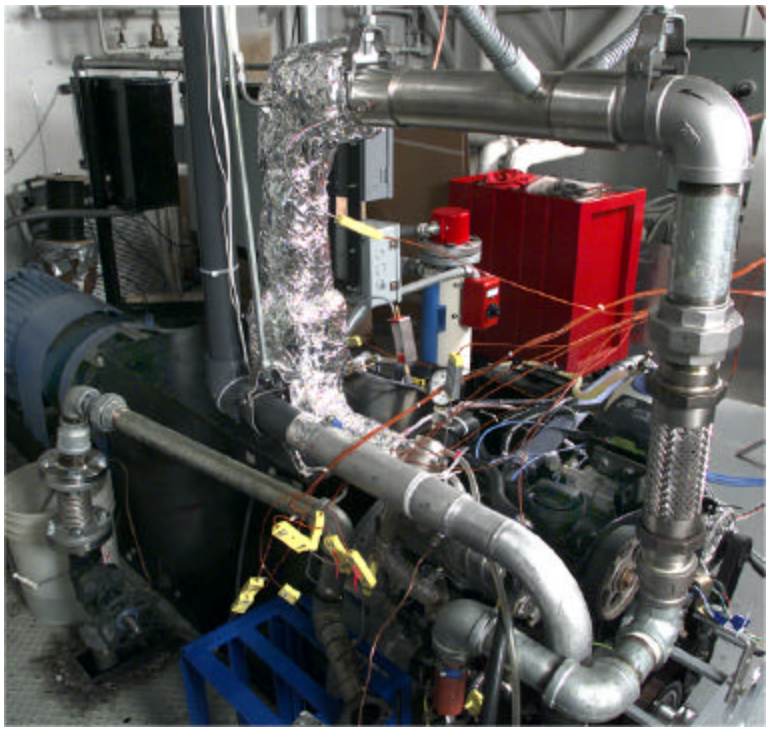
Aerodynamic drag experiments and analysis

Auxiliary Systems

Sensors -- Increasingly stringent emissions regulations will require automobile manufacturers to reduce exhaust gas pollutants in the near future. Compact, inexpensive, on-board diagnostic sensors will be needed for monitoring and control of regulated pollutants including oxides of nitrogen (NO_x), hydrocarbons, and carbon monoxide. Because the need for these sensors is fairly recent, very few sensors of any kind are available. The principal challenges associated with development are sensitivity, response time, and sensor stability. LLNL currently has an experimental effort to develop electrochemical gas sensors for various automotive applications. This effort approaches the problem of sensor performance by the application of novel materials and fabrication processes designed to optimize electrode microstructures. A NO_x sensor with fast response time and high sensitivity has been developed for monitoring compression ignition direct ignition (CIDI) exhaust. This sensor is currently entering the prototype phase. In addition, a rugged, low-cost, solid-state electrochemical sensor for monitoring non-methane hydrocarbons (Mac's) has been developed. That sensor was dynamometer tested in U.S. Council for Automotive Research partner laboratories and appears to be one of the most promising hydrocarbon sensors to undergo such preliminary testing. Similar technology for hydrogen sensors to be used as part of the safety system around hydrogen fuel cells is also being developed. martin89@llnl.gov

Engines and Combustion

HCCI -- HCCI is a new combustion methodology that yields the high efficiency of diesel engines without the high nitrogen oxide (NO_x) and particulate matter (PM) emissions. However, several hurdles stand in the way of successful HCCI engine commercialization. These include robust control of combustion timing, low power output, obtaining consistent combustion timing in different cylinders of a multi-cylinder engine, and engine start ability. We are addressing these challenges through a combination of analytical and experimental techniques. We have developed advanced analysis techniques that allow us to calculate all parameters of HCCI combustion with high accuracy, and we have applied these models to explain the fundamentals of HCCI combustion. We also have an experimental effort aimed at controlling ignition and balancing combustion between the cylinders of a multi-cylinder engine. saceves@llnl.gov



Experimental multi-cylinder HCCI engine, converted from a Volkswagen TDI diesel engine

Analysis of New Combustion Regimes and Hydrogen Engines -- Recent years have witnessed the emergence of new combustion regimes that are aimed at improving engine efficiency while reducing emissions. These include MK and smokeless rich combustion (also known as low-temperature combustion). In addition to this, the effort to advance the hydrogen economy has resulted in increased interest in hydrogen engines. We have expertise in chemical kinetics and fluid mechanics that allows us to successfully conduct detailed analysis of these operating regimes and fuels. We are working with industry and other national laboratories in an effort to develop a deep understanding of the processes that control combustion in these regimes. This understanding will facilitate commercialization of these new technologies. dflowers@llnl.gov

Emissions Reduction Technologies

Fundamental Analysis of NO_x Traps -- Diesel engines cannot meet future emissions standards without aftertreatment. Currently, aftertreatment systems are impractical because of cost, complexity, durability and efficiency penalty. NO_x traps are the preferred technology for NO_x aftertreatment in lean burn engines. However, very little is known about the fundamental chemical kinetics that dominate the process of NO_x adsorption and desorption on the catalyst surface. Greater scientific understanding of NO_x traps will facilitate breakthrough technological improvements.

We are using advanced analysis techniques (molecular dynamics and kinetic Monte Carlo) to evaluate the basic energetics of adsorption and desorption reactions of NO_x into catalyst substrates. These calculations will allow us to generate the basic chemical kinetics equations that then can be applied in a thermo-fluids model of the NO_x trap. The purpose is to develop analysis methodologies that industry can help to design efficient and durable NO_x traps. pitz1@llnl.gov

Materials

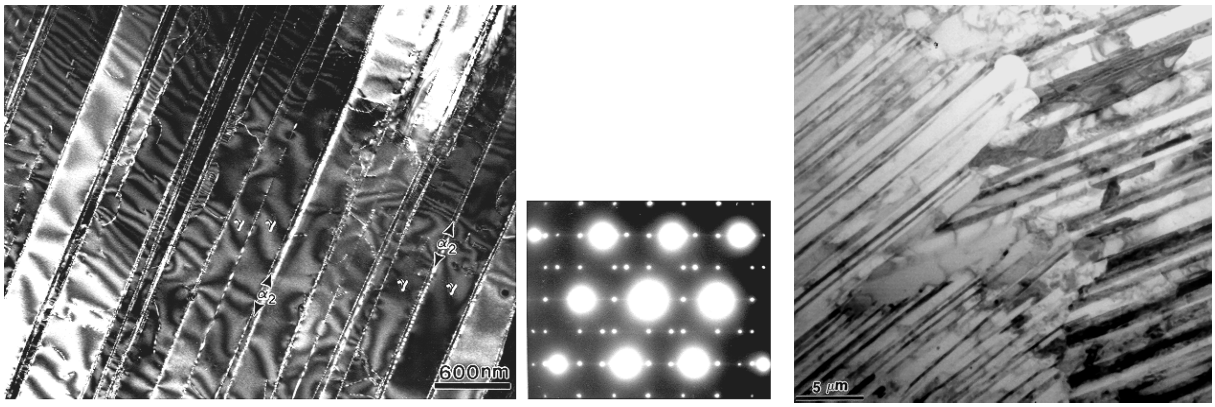
Composite Materials **--** LLNL has developed analytical and numerical tools that efficiently predict the behavior of carbon-fiber composites in vehicular crashworthiness simulations. We have focused specifically on fabric and braided-fiber architectures molded with a polymeric matrix and consider loading conditions and strain rates that arise in vehicular impacts. **zywicz1@llnl.gov**, deteresa1@llnl.gov

Magnesium Casting **--** Driven by the need to reduce our consumption of fuel, significant emphasis is placed upon lightening our automobiles. Magnesium offers the potential to provide lighter cars and still maintain the same if not improved structural integrity. LLNL has extensive nondestructive evaluation capabilities and experience that provide a unique resource to support development of new and improved metalcasting techniques. As part of the Structured Cast Magnesium Development cooperative research and development agreement, LLNL is conducting nondestructive evaluations to not only evaluate the structural integrity of magnesium automotive components but also to assist in the selection and optimization of casting parameters. **prindiville1@llnl.gov**

Development of Ultrafine Lamellar Titanium-Aluminum Alloys -- The objective of this effort is to design and fabricate ultrafine lamellar TiAl alloys for advanced diesel engine applications. The primary goals of this project is to exploit advanced thermomechanical processing techniques to fabricate lamellar TiAl alloys with the size of lamella width down to submicron and/or nanometer region. The purpose is to (1) experimentally verify microstructural stability and mechanical properties (room-temperature ductility and strength and elevated-temperature creep resistance) of the ultrafine lamellar alloys and (2) investigate the fundamental interrelationships among processing, microstructures, alloying additions, and mechanical properties of the ultrafine lamellar alloys so as to achieve the desired properties and performance of the alloys for high-temperature structural applications.

Two-phase [TiAl (γ-$L1_0$) and Ti_3Al (α_2-DO19)] lamellar TiAl alloys have recently attracted great attention because of their low density (ρ = 3.9 g/cc), high specific strength, adequate oxidation resistance, and good combination of ambient-temperature and elevated-temperature mechanical properties. These characteristics are of interest for engineering applications, such as high-temperature components in diesel engines. Through alloy design and microstructural optimization, significant progress has been made to improve both room-temperature ductility/toughness and high-temperature creep resistance of the alloys.

The result of a preliminary effort has revealed that the alloys fabricated by hot extrusion at 1,400°C can form a refined lamellar microstructure, as shown in the figure below. The hot-extruded lamellar alloys provide a better combination of room-temperature and high-temperature mechanical properties than those of lamellar TiAl alloys fabricated by conventional ingot metallurgy. Accordingly, there is great interest in further refining lamellar spacing of the alloys to submicron- or nanometer- length scales to develop nano-lamellar TiAl alloys for engineering applications. hsiung1@llnl.gov



(a) (b)

(a) A dark-field TEM image showing a typical lamellar microstructure observed from $Ti_{47}Al_2Cr_2Nb$ extruded at 1,400 °C, and an SAD pattern generated from the domain in (a). (b) A bright-field image showing an interwoven colony boundary in the lamellar TiAl alloy.

OAK RIDGE NATIONAL LABORATORY

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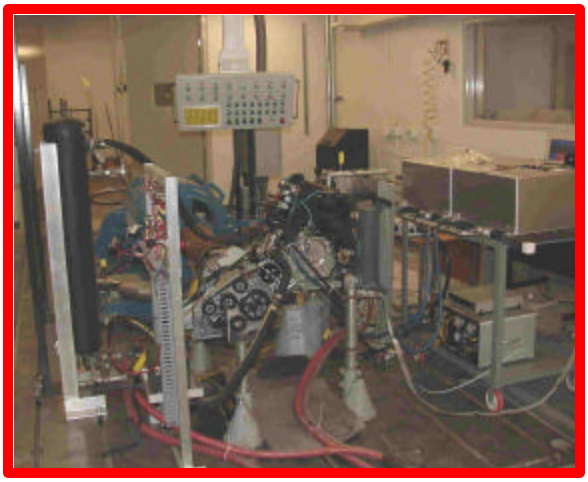
CAPABILITIES

Fuels, Engines, and Emissions Research Center

The Fuels, Engines, and Emissions Research Center (FEERC) specializes in the detailed characterization and studies of internal combustion engine emissions, efficiency, and fuel effects. The facility's comprehensive capabilities include an analytical lab with bench-top engine exhaust simulators, a wide range of engine dynamometers, and a chassis dynamometer for full vehicles. The FEERC boasts several special diagnostic and measurement tools — including many rarely found at other facilities around the country — that aid in development and evaluation of engine and emission control technologies. The FEERC was originally designated a DOE National User Facility in 1999 as the Advanced Propulsion Technology Center.

Key Laboratory Capabilities **--** The analytical laboratory houses the bench flow reactor, mass spectrometry, chemisorption, and laser diagnostics laboratory. Infrared spectroscopy and laser-phosphor thermography are in adjacent labs.

The engine dynamometer cells range from 10 to 600 hp, several with motoring capability. Provisions for highly controlled measurements of aftertreatment device performance are available.



One of five typical engine research cells, this one houses a small direct-injection diesel engine with full-pass control over major engine calibration parameters

Emission control R&D frequently requires use of chassis dynamometers because regulations and "real-world" simulation mandate transient cycles with vehicles. The FEERC chassis dynamometer can handle about 300 hp.

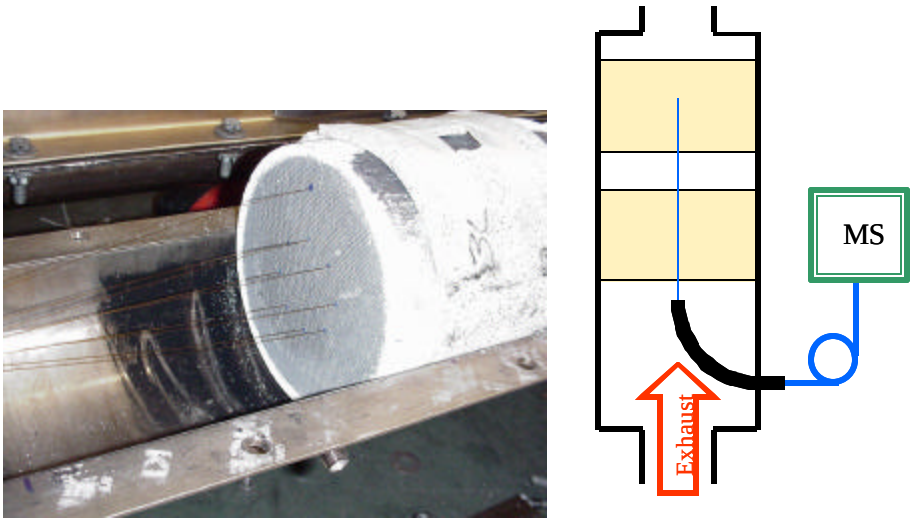
A dSpace-based full-pass engine control system provides capability in integrating engine functions with aftertreatment systems. Emissions measuring equipment is ready for NOx, CO, hydrocarbons, particulates, including FTIR, Fast FID, Fast-NO.

A fast response, direct sampling mass spectrometer for diagnostics of emission control devices (an ORNL innovation) is sufficiently robust for use in the dynamometer cells. Exhaust volatile and semi-volatile constituent speciation can be performed. Exhaust particle characterization is done by the following methods:

- time-integrated mass measurement on filters, near-real-time measurement by tapered element oscillating microbalance (TEOM), particle sizing by micro-orifice uniform deposit impactor (MOUDI) system and scanning mobility particle sizer (SMPS).
- Near-real-time optical particulate measurement via diesel particle scatterometer (a Lawrence Berkeley innovation implemented at ORNL).
- On-site PM composition analysis.
- Transmission electron microscopy, in the High Temperature Materials Laboratory, for morphology.

The vehicle dynamometer has approximately 300-hp absorption capacity and can accommodate the above-mentioned emissions instrumentation. The Center's staff includes specialists in emissions measurements, dynamometer cell operations, and engine controls and control theory.

Current and Recent Research Activities -- Current R&D projects at the Center include determining the effects of fuel sulfur on diesel emissions controls, diesel and gasoline engine-particle emissions, advanced engine control and combustion strategies, such as "low-temperature combustion," and catalyst surface diagnostics. The Center is also active in research projects on diesel emission control via NO_x adsorber catalysts, urea selective catalytic reduction (SCR), exhaust gas recirculation (EGR), particulate filters, and controls with virtual sensing. Fuel-property studies on performance and emissions have included ethanol-diesel fuel blends, ultra-low



An analytical tool developed at ORNL, the "spatially resolved mass capillary input mass spectrometry" (SpaciMS), enables the spatial and temporal resolution of species in functioning catalysts. An electronic valve switches SpaciMS input between sample locations.

sulfur diesel fuels, and biofuels. The direct sampling capillary mass spectrometer is finding use in studies of catalyst functions and EGR. For spark ignition engines, the center has gasoline direct-injection engines and vehicles available for research, as well as natural gas engines. Innovative ignition concepts are being developed. In the analytical lab, NO_x sensors are being studied

for time response and sensitivity. Previous work includes *in-situ* engine cylinder-wall oil-film diagnostics, applications of laser phosphor thermography of in-cylinder components, and mapping of vehicle emissions and fuel use in on-road modes.

National Transportation Research Center

The National Transportation Research Center (NTRC) offers one of the largest multidisciplinary concentrations of transportation researchers in the United States, housing R&D programs and laboratories from Oak Ridge National Laboratory (ORNL) and The University of Tennessee (UT). The NTRC was established to develop and evaluate advanced transportation technologies and systems and to help the transportation industry deal with technology issues. The NTRC seeks to assist industry in utilizing state-of-the-art hardware and computing technologies to address problems of national and international significance, such as declining air quality, dependence on unstable oil supplies, traffic congestion, and highway safety.

The NTRC houses several user centers that focus on different aspects of transportation, including commercial vehicle operations, supply chain management, commercial and military transportation logistics, geographic information systems, infrastructure materials, remote sensing, and heavy vehicle safety. Three user centers funded by the FreedomCAR and Vehicle Technologies Program are:

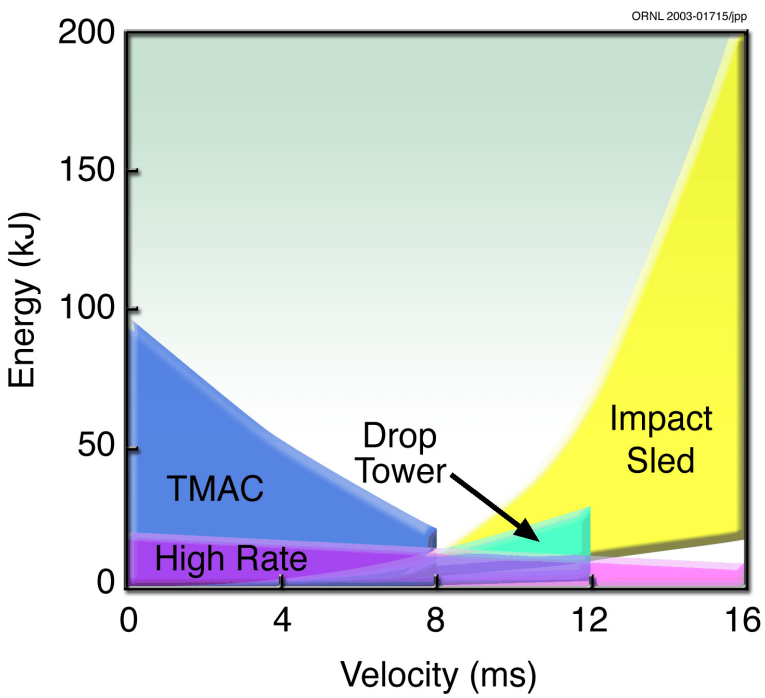
- Composite Materials Laboratory, which conducts controlled, programmable analysis of the deformation and failure response of lightweight materials in relation to impact velocity

- Fuels, Engines, and Emissions Research Center, which specializes in the detailed characterization of internal combustion engine emissions and efficiency

- Power Electronics and Electric Machinery Research Center, which develops next-generation, cost-effective converters, adjustable-speed drives, motor controls, and efficient, compact electric machines.

Composite Materials Laboratory -- Advanced lightweight materials, such as polymer composites and high-strength steels, offer better crash energy absorption per unit of mass than do traditional materials. When those materials are tested to assess their response to crushing, they exhibit different behaviors at different impact velocities. What happens in the transition zone between quasi-static impact rates (for example, 0.058 m/min) and high-velocity impacts (over 16 km/h) is not understood because the capability to conduct impact tests at intermediate velocities has been lacking. The Composite Materials Laboratory operates a unique servo-hydraulic test machine, the Integrated Physical and Virtual Test Machine for Automotive Crashworthiness (TMAC), to fill that gap.

The TMAC is capable of conducting progressive crushing tests on composite automotive components at velocities ranging from 0 to 29 km/h and energy levels up to 50kJ. Using this machine, researchers can study component deformation and failure response in relation to impact velocity in a controlled and programmable manner that is made possible by a unique adaptive control feature of the software. The capability to test across this range of velocities and energy levels is providing the critical data needed for crash simulations that assess the safety of vehicle body structures manufactured from composites and other lightweight materials.



Shaded areas compare the ranges of data collected by the TMAC and by other methods.

The TMAC was installed in October 2002. It was developed and funded through collaboration between DOE and the U.S. Council on Automotive Research's (USCAR) Automotive Composites Consortium (ACC). The ACC identified the need for this capability; ORNL and the ACC jointly developed the specifications for the machine; and MTS Systems, Inc., designed and built the machine.

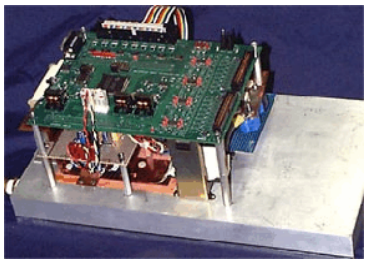
Fuels, Engines and Emissions Research Center -- The FEERC specializes in detailed characterization of internal combustion engine emissions and efficiency. The facility's comprehensive capabilities include bench-top engine exhaust simulators, a wide range of dynamometers, and full vehicles. The FEERC boasts several special diagnostic and measurement tools — including many rarely found at other facilities around the country, plus unique instruments developed by Center staff — that aid in development and evaluation of engine and emission control technologies. The FEERC was originally designated a National User Facility in 1999 as the Advanced Propulsion Technology Center.

Full-vehicle research complements bench-scale and engine dynamometer capabilities

Current R&D at the center includes determining the effects of fuel sulfur on diesel emissions controls, gasoline and diesel engine particle emissions, advanced engine control strategies, and catalyst surface diagnostics. The Center is also active in research projects on emission control via NO_x adsorber catalysts, urea selective catalytic reduction (SCR), exhaust

gas recirculation (EGR), particulate filters, and controls with virtual sensing. Fuel property studies on performance and emissions have included ethanol diesel fuel blends, new ultra-low sulfur diesel fuels, and biofuels. The direct sampling capillary mass spectrometer is finding use in studies of catalyst functions and EGR. For spark ignition engines, the center has gasoline direct injection engines and vehicles available for research, as well as natural gas engines. Innovative ignition concepts are being developed. In the analytical lab, NO_x sensors are being studied for time response and sensitivity. Previous work includes in-situ engine cylinder-wall oil- film diagnostics, applications of laser phosphor thermography of in-cylinder components, and mapping of vehicle emissions and fuel use in on-road modes.

Power Electronics and Electric Machinery Research Center -- The staff of the Power Electronics and Electric Machinery Research Center (PEEMRC) is recognized worldwide for their expertise in developing and prototyping advanced power converters, adjustable speed drives, and electric machines; power transmission and distribution research and development; and power quality, efficiency, and measurement. The Center provides unique expertise in power converter topologies, thermal management, packaging technologies for minimization of electromagnetic interference and for space and weight reduction, DSP-based control techniques for motor drives, system energy management, flywheel energy storage applications, and ultra-high speed drive applications.



The compact topology of this dc/dc converter for fuel cell systems can power a high-voltage compressor motor expanding unit from a low voltage battery until fuel cell voltage is established.

This expertise is applied to transportation to enable electric and/or hybrid vehicle traction drives, motor-assisted turbochargers, electric air-conditioners, fuel cell converters, and other auxiliary drives. The PEEMRC is working with industrial partners to develop and evaluate automotive electric motor drive units and automotive integrated power modules, and to address system integration issues. PEEMRC researchers use and develop the latest analysis, simulation, and design software to provide proof of principle prior to hardware implementation of their circuit and motor designs.

The PEEMRC also addresses power electronics and electric machinery technology needs, as well as issues in other areas, such as electric power transmission and distribution, distributed energy generation systems, and motors and drives for special applications. Equipment available in the PEEMRC includes a dedicated 600-V, 600A, bi-directional dc power supply; a high-speed rotational equipment safety tank; and a 100-hp, 10,000-rpm, 4-quadrant dynamometer.

High Temperature Materials Laboratory

The Facility -- The High Temperature Materials Laboratory (HTML) is a facility designed to assist American industries, universities, and Governmental agencies develop advanced materials by providing a skilled staff and numerous sophisticated, often one-of-a-kind pieces of materials characterization equipment. It is a nationally designated user facility sponsored by the DOE's FreedomCAR and Vehicle Technologies Program in the Office of Energy Efficiency and Renewable Energy. Physically, it is a 64,500 sq. ft. building on the ORNL site, in which reside six "user centers," which are clusters of specialized equipment revolving around a specific type of properties measurements. Expansion of the HTML User Program since its inception in 1987 has made available new equipment and instrumentation located in other buildings of the Metals and Ceramics Division. HTML users also now have access to the X-14A x-ray beamline at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory and a neutron diffraction instrument located at the High Flux Isotope Reactor at ORNL.

The HTML was conceived and built in the mid-1980's to provide a facility that would directly work with American industry, academia, and Government labs to provide advanced high-temperature materials, such as structural ceramics for energy-efficient engines. The scope of the HTML's work has since expanded to include other, non-high-temperature materials of interest to transportation and other industries.

The User Centers

Materials Analysis User Center (MAUC) -- Researchers in this Center employ electron microscopy and surface chemical analysis to determine structure, surface chemistry, and microstructure to the atomic level. Instruments include a Hitachi HF-2000 transmission electron microscope (TEM), a Hitachi HD-2000 scanning transmission electron microscope (STEM), a new JEOL 2010F STEM/TEM, a Phi 680 Scanning Auger nanoprobe, and a Hitachi focused ion beam instrument.

Mechanical Characterization and Analysis User Center -- Researchers in this Center study the fracture toughness, tensile strength, flexure strength, and tensile creep of advanced materials at temperatures to 1,500?C in air or controlled atmospheres. Instruments include nearly a hundred creep frames, several outfitted with atmosphere control, numerous MTS, ATS, and Instron mechanical test frames for tensile, compressive, or bending testing at elevated temperatures. The center also has nanoindentation and fiber-composite characterization capabilities, ranging from individual fibers to complete composite structures.

Residual Stress User Center --This Center has two principal parts: x-ray diffraction and neutron diffraction. The x-ray portion includes x-ray diffractometers to measure residual stress and texture in and near the surface of ceramics and alloys. Users can also access the NSLS at Brookhaven National Laboratory through this user center. The neutron residual stress facility includes a special neutron spectrometer for rapid data collection, plus computer capabilities for data analysis. The spectrometer instrumentation is located at the High Flux Isotope Reactor.

Diffraction User Center -- This Center has both room-temperature and furnace-equipped x-ray and neutron diffractometers. The x-ray furnace is used for studies of materials properties at temperatures up to 2,700?C in vacuum and up to 1,500?C in air. This Center also has access to the NSLS synchrotron mentioned above.

Thermophysical Properties User Center -- Researchers in this Center study thermal stability, expansion, and thermal conductivity of materials to greater than 1,400?C. Instruments include a Netzsch DSC, a Theta dual-pushrod dilatometer, and a laser flash instrument to measure thermal diffusivity to temperatures of 1,900?C. A separate capability is that of thermal mapping, utilizing a high-speed, high-sensitivity infrared camera.

Machining, Inspection, and Tribology Research User Center -- This Center employs instrumented surface and cylindrical grinders to study hard material grinding on ceramics and special alloys. These grinders include high-stiffness surface grinders, a cylindrical grinder, and a creep-feed surface grinder. Other capabilities include instruments for determining the cylindricity and circularity of axially symmetric objects. A coordinate measuring machine is available. Also, this Center contains equipment for the measurement of friction and wear, including fretting, rolling, and sliding.

The HTML Programs -- Within the HTML are programs that function to help outside researchers solve materials problems using state-of-the-art characterization instrumentation. In the "HTML User Program," either non-proprietary or proprietary research can be performed by American industrial and academic researchers. The former is provided free of charge if the user publishes the information produced, while the latter requires payment. Non-proprietary research projects typically last from 1 to 3 weeks at the HTML. The major proviso is that the results must be submitted for publication within 6 months after completion of the research.

For proprietary research, the user and the HTML staff estimate the cost of HTML staff time required to complete the work. The user agrees to pay for this time at an hourly rate specified by the DOE before the start of the research. These projects typically are more extensive than non-proprietary projects, and the user owns the data from the research.

For Further Information

http://www.ntrc.gov/
http://feerc.ornl.gov
http://www.ms.ornl.gov/htmlhome/

NATIONAL RENEWABLE ENERGY LABORATORY

As a world leader in renewable energy and energy efficiency research, the National Renewable Energy Laboratory (NREL) is developing new transportation technologies to benefit both the environment and the economy. Through NREL's Center for Transportation Technologies and Systems, we develop and demonstrate innovative technologies that will allow alternative fuels and advanced vehicle systems to supply a significant portion of the Nation's transportation needs.

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CAPABILITIES

Fuels and Engine Testing

NREL works with Government and industry to research and develop alternative diesel fuels and lubricants, such as biodiesel and E-diesel. The laboratory also leads efforts to improve petroleum-based diesels by researching ultra-low sulfur fuels, advanced engines, and catalysts. We use our facilities to identify, test, and evaluate fuels, lubricants, and engines that will allow manufacturers to meet 2007 emissions requirements while maintaining vehicle performance and fuel efficiency.

Component and Systems Math Modeling and Energy-Efficient Optimization

The laboratory's research into battery performance and auxiliary load reduction allows industry to increase fuel efficiency and reduce emissions. As part of this effort, we work with vehicle manufacturers to improve thermal management systems—from the cell level to the battery pack—for electric, hybrid-electric, and fuel-cell vehicles. NREL also leads efforts to reduce vehicle auxiliary loads, such as air-conditioning, by evaluating advanced window glazings, cooling heat-pipe systems, and parked car ventilation.

Vehicle Simulation—Heavy- and Light-Duty Vehicles

Because energy management strategies depend on accurate vehicle simulation, NREL has developed and commercialized a software package that effectively models vehicle efficiency, performance, and emissions. This package, known as ADVISOR™ (ADvanced VehIcle SimulatOR), allows for virtual testing of vehicle components and systems.

Advanced Heavy-Hybrid Propulsion Systems

Researchers at NREL are working with industry to develop advanced, heavy-vehicle hybrid propulsion components and systems. These systems are expected to significantly improve heavy-vehicle fuel efficiency and reduce emissions. By teaming with industry, we are able to take advantage of the best technologies and skills available from various companies and organizations.

Fleet Evaluations

NREL collaborates with industry and Government fleets to develop fleet test procedures and data-collection plans to evaluate vehicle emissions, maintenance, costs, and performance. We also lead innovative projects designed to demonstrate prototype and production engines and vehicles.

Emissions and Air Quality Research

To better understand the problem of transportation-derived air pollution, researchers examine ambient air samples and exhaust emissions data to determine the effects of pollutants on human health and air quality. Vehicles are tested while operating on traditional and advanced fuels.

Technology Integration

NREL works with the U.S. Department of Energy's Clean Cities Program to help build a sustainable alternative fuels market in participating cities across the Nation. The laboratory also maintains the Alternative Fuels Data Center, which is the most comprehensive resource for information on advanced and alternative transportation technologies and systems in the United States. To access the AFDC on the Web, visit www.afdc.doe.gov.

Fuel Cells and Hydrogen

As worldwide interest in hydrogen and fuel-cell technology increases, NREL continues to work directly with DOE and its subcontractors to develop fuel-cell technologies for vehicle applications.

UNIQUE FACILITIES/EQUIPMENT/CAPABILITIES

ReFUEL Laboratory

The ReFUEL (Renewable Fuels and Lubricants) laboratory is a unique, high-altitude facility for testing alternative and advanced fuels and heavy-duty engines and vehicles. The lab is equipped with a heavy-duty chassis dynamometer, an engine test cell, and emissions measurement equipment compliant with the 2007 Code of Federal Regulations. The laboratory is capable of testing conventional and alternative diesel fuels, heavy-hybrid vehicles, and conventional diesel engines.

Fuel Chemistry Laboratory

The Fuel Chemistry lab is equipped with an Ignition Quality Tester™ (IQT). Researchers use the IQT to characterize the effect of the molecular structure of blending components on ignition properties. The laboratory is also equipped with a gas chromatograph and a high-performance liquid chromatograph for speciating and quantifying unregulated toxic compounds emitted in vehicle exhaust streams. This allows us to compare emissions from engines running on conventional fuels with those using alternative fuels.

Thermal Management Test Facility

The Battery Thermal Management Test Facility houses a unique calorimeter for measuring battery performance and thermal imaging equipment for diagnosing battery behavior. The laboratory also contains a bidirectional battery cycler, which can meet the most demanding driving-cycle profiles, including those of the Federal Urban Driving Schedule and the General Dynamic Stress Test.

Ancillary Loads Reduction Laboratory

The Ancillary Loads Reduction laboratory is focused on improving vehicle fuel economy and reducing emissions by decreasing vehicle auxiliary loads, such as air-conditioning, while maintaining passenger comfort. Engineers at the laboratory conduct vehicle tests and develop integrated models to evaluate the impacts of advanced window glazing, cooling heat-pipe systems, parked car ventilation, ventilated seats, and direct-energy recovery and adsorption-cooling systems. A life-size thermal manikin is also used to evaluate passenger comfort using advanced climate control concepts.

PATENTS AND AWARDS

NREL's Center for Transportation Technologies and Systems has been awarded more than 10 patents and records of invention and 2 R&D 100 awards.

RECENT AND ONGOING EFFORTS

NREL collaborates with fuel, engine, and vehicle manufacturers as well as other Federal laboratories and university research organizations. Some of our recent research partners include:

3M
Allison Transmission
American Chemistry Council
API
ArvinMeritor
BAE Systems
Battelle
Benteler
BP
California Air Resources Board
California Fuel Cell Partnership
Castrol
Caterpillar, Inc.
Chevron Oronite
Chevron Texaco
Ciba
Clean Diesel Technology
Conoco-Phillips
Controls Freightliner
Corning
Crompton
Cummins Engine Company
DaimlerChrysler
Delphi Automotive Systems
Detroit Diesel Company
Donaldson Co.
Eaton
Engelhard
Engine Manufacturers Association
Ergon
Ethyl
ExxonMobil
Ford Motor Company
General Motors
Honeywell International
Infineum
International Truck & Engine
John Deere
Johnson Matthey
Lubrizol
Mack Trucks
Marathon Ashland
MECA
Motiva
NGK
NovaBus
NPRA
OMG
Oshkosh Trucks
PACCAR
Pennzoil-Quaker State
Rhodia
Robert Bosch Corp.
Shell Global Solutions
Siemens
South Coast Air Quality Management District
STT Emtech AB
Tenneco Automotive
Toyota
Truck Manufacturers Association
University of California, Berkeley
University of West Virginia
University of Wisconsin
Valvoline
Volvo Trucks North America

FOR FURTHER INFORMATION

Please visit NREL's Center for Transportation Technologies and Systems on the Web at www.ctts.nrel.gov.

PACIFIC NORTHWEST NATIONAL LABORATORY

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CAPABILITIES

Emissions Science

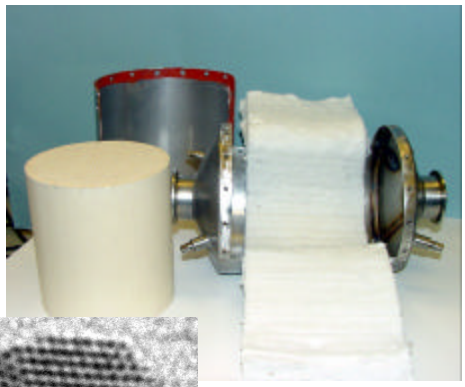
The Exhaust Chemistry & Aerosol Research Laboratory at the U.S. Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) offers the necessary resources for the development and testing of emissions-control technologies and catalyst materials under real-life operating conditions. The objective of this laboratory is the application of the chemical and physical sciences to solve engineering problems related to the development of emission control technologies and improving existing devices.

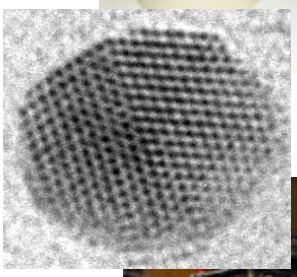
PNNL's research and development activities in the area of emissions-control technologies focus on:

- Emissions Chemistry Characterization
- Particulate Measurement and Characterization
- Catalyst Development and Characterization
- Reaction Mechanism Identification
- Aftertreatment Prototype Development
- Prototypical Device and Systems Testing
- Chemical and Physical Property Sensor Development

PNNL is working with industry and academia to solve many technology hurdles related to emission controls and improving the fundamental understanding of the chemistry involved in aerosol, gas-phase and surface reactions.

Emissions Control





PNNL has broad capabilities in the area of catalyst development and characterization, as well as characterization of chemical and physical processes used for the abatement of pollutants from mobile and stationary internal combustion engines. PNNL works with industry partners on technologies ranging from hydrocarbon (HC) - and urea-selective catalytic reduction (SCR) to NO_x and SO_x traps to particulate filtration and trap regeneration. Much of this work involves developing a detailed understanding of the chemical and physical processes that occur, what the degradation mechanisms are, and how to control the process to achieve a high level of performance and durability.

PNNL and its partners have been successful at developing and improving technologies used for emissions reduction from diesel engines and other reciprocating internal combustions engines.

Sensors and Electronics

Aftertreatment devices require on-board diagnostics to monitor the performance of the aftertreatment devices. PNNL has broad capabilities and experience in the development of innovative sensors, measurement methods, and systems to meet diverse client requirements. PNNL has worked with industrial partners for oxygen and NO_x sensors for automotive applications.

Fuel Reforming

Small and efficient microchannel fuel reformers are being developed by PNNL for use with proton-exchange membrane (PEM) fuel cells. PNNL, together with the National Energy Technology Laboratory as a part of the Strategic Energy Conversion Alliance, is developing low-cost, high-efficiency, solid-oxide fuel cells for auxiliary power on heavy vehicles, military vehicles, and automotive applications. Invention reports have been filed in the area of seals and solid-oxide fuel cell processing.

PNNL is also working with industry partners to develop diesel fuel reformation technologies for applications to improving the performance of lean-NO_x catalysis and other exhaust after-treatment devices for diesel-powered vehicles.

Environmental Molecular Sciences Laboratory

The Environmental Molecular Sciences Laboratory (EMSL) at PNNL is a national scientific user facility and research organization that

- provides advanced resources to scientists engaged in fundamental research on the physical, chemical, and biological processes
- conducts scientific research and advances molecular and computational sciences
- educates scientists in the molecular and computational sciences to meet the demanding environmental challenges of the future.

The EMSL campus offers – at one location – a comprehensive array of leading-edge resources for research in the environmental and molecular sciences, such as

- Gas- and liquid-phase monitoring and detection facility
- High-field magnetic resonance facility
- High-field mass spectrometry facility
- Interfacial structure and compositions facility
- Molecular science computing facility
- Nanoscience and technology facility
- Optical imaging and spectroscopy facility
- Reactions and interfaces facility.

Engineering Simulation and Modeling

The internally funded engineering simulation and modeling activities at PNNL are part of an overall computational science and engineering initiative and are currently focused on thermo-plastic composites materials, manufacturing activities, and hydrogen materials. PNNL has state-of-the-art computational facilities and unique software development and application capabilities. Projects are conducted with a broad range of industry, national laboratory, and university partners.

Emission Modeling – NO_x, CO, HC's, Particulates

- Guide future catalyst system development, characterization
- Identity after-treatment bottlenecks (system and component sensitivity analysis)
- Evaluate impact of fuel reformulations, engine changes
- Develop new devices for NO_x reduction and sensing
- Conduct research and development (R&D) on particulates reduction and capture
- Perform system modeling

Advanced Materials and Manufacturing Research and Development

- Materials Science technologies
    - Lightweight metals (aluminum, magnesium, titanium, metal composites)
    - High-strength steel
    - Polymer composites
    - Glazing (glass) materials
    - Ceramics and porous structures (catalysts, membranes, electrical devices)
- Metal casting and forming technology development
- Polymer composite manufacturing
- Ceramics processing
- Coatings and thin-film technologies
- Advanced joining technologies of monolithic, composite and dissimilar materials
- Materials and manufacturing modeling and finite element analysis

PATENTS AND AWARDS

PNNL's activities have led to commercial products and over 35 patents, as well as R&D 100 Awards for innovative technology developments, FLC Awards for Excellence in Technology Transfer, and a Discover Award.

RECENT AND ONGOING EFFORTS

PNNL has forged successful working partnerships with a number of major engine and vehicle manufacturers, as well as universities and other DOE laboratories. These include:

Caterpillar
Cummins
DaimlerChrysler
Delphi Corporation
Detroit Diesel Corporation
Ford Motor
General Electric
General Motors
Lawrence Livermore National Laboratory
Northwestern University
Oak Ridge National Laboratory
Sandia National Laboratories
U.S. Council on Automotive Research - Low Emissions Technologies Research and Development Partnership
University of Maryland

FOR FURTHER INFORMATION

http://www.pnl.gov/auto/
http://www.emsl.pnl.gov.

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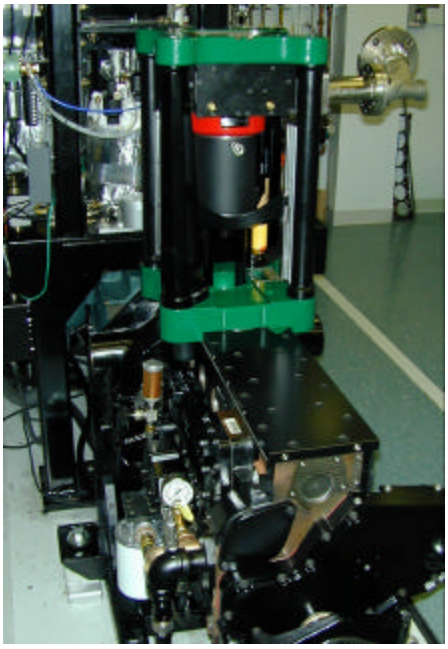
CAPABILITIES

The engine combustion research program at the Combustion Research Facility (CRF), Sandia National Laboratories has closely interacted with U.S. engine manufacturers for more than 25 years to promote the fundamental understanding of in-cylinder processes governing efficiency and emissions. This information is being used by OEMs in their effort to develop more efficient engines that meet stringent new emissions standards for passenger vehicles, light-duty trucks, and heavy-duty transport vehicles. A current emphasis in the program is on developing the science-base for low-temperature combustion (LTC) processes, *e.g.*, homogeneous charge compression ignition (HCCI) and various forms of stratified charge compression ignition (SCCI) combustion. Low-temperature combustion strategies offer the potential for diesel-like efficiencies and extremely low emissions of NO_X and particulates. In our research, we employ advanced, laser-based diagnostics in conjunction with experimental hardware that closely mimics realistic engines while providing optical access. We are also investigating alternative fuel property effects on combustion and emission processes and are developing new diagnostic techniques such as laser-induced incandescence (LII), laser-induced desorption with elastic light scattering (LIDELS), and laser induced breakdown spectroscopy (LIBS) for real-time characterization of particulate matter emissions from engines.

UNIQUE FACILITIES/EQUIPMENT/CAPABILITIES

Homogeneous Charge Compression Ignition/Stratified Charge Compression Ignition Dual-Engine Laboratory

Because of the high-efficiency and low emissions potential of homogeneous charge compression ignition/stratified charge compression ignition (HCCI/SCCI), both automotive and diesel engine manufacturers are actively developing these combustion strategies. Sandia's HCCI/SCCI Dual-Engine Laboratory is supporting this industrial effort by providing understanding of the fundamental processes controlling HCCI/SCCI. The laboratory houses two 6-cylinder Cummins B-series engines converted for balanced, single-cylinder HCCI/SCCI operation: (1) an all-metal engine capable of speeds to 3,600 rpm for determining engine performance in various operating modes, investigating emissions, and developing combustion-control strategies and (2) an optically accessible engine, modified with an extended cylinder and windows into the combustion chamber, capable of speeds to 2,100 rpm, for the application of advanced laser-based diagnostics to the investigation of in-cylinder processes.



Optically Accessible HCCI/SCCI Engine

The two engines are mounted on opposite ends of a 125-hp dynamometer and share a common intake system capable of providing boost pressures up to 4 bars, intake temperatures up to 220°C, and simulated or real exhaust gas recirculation (EGR). These engines displace 0.98 liter/cylinder (a size typical of sport-utility vehicles or medium-duty diesels), have a 4-valve head modified to provide variable swirl ratios from 0.9 to 3.2, and accommodate compression ratios from 12:1 to 21:1. Fueling systems include a centrally mounted direct injector (for either gasoline- or diesel-type fuels), port fuel injectors, or a fully premixed fueling system. The laboratory is equipped with complete exhaust gas analysis instrumentation (HC, O_2, CO, CO_2, NO_X, and smoke), in addition to cylinder-pressure analysis and optical diagnostics. Recent and current research efforts are directed at understanding the sources of HC and CO emissions, investigating the effects of fuel type, determining the role of heat transfer in controlling combustion phasing, studying intake-pressure boosting to extend the load range, and investigating partial charge stratification as a method for improving low-load combustion efficiency, controlling combustion phasing, and extending the operating range.

Automotive HCCI Engine Laboratory

In the near term, the application of HCCI to automotive engines will likely involve a mixed-mode combustion concept in which HCCI is used at low-to-moderate loads and standard spark-ignition (SI) combustion at higher loads. This type of operation using standard gasoline-type fuels requires a moderate compression ratio of 10:1 to 14:1 for SI operation and significant intake heating for HCCI operation (typically provided by retaining a high fraction of residuals). The Automotive HCCI Engine Laboratory houses a versatile light-duty engine designed to allow investigations of a wide variety of issues for this type of HCCI application.

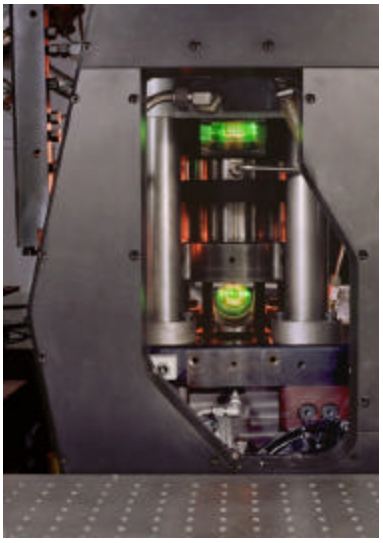
Optically Accessible
Automotive HCCI Engine

This automotive-sized engine (0.63 liter/cylinder) has a 3-valve pent-roof head and is equipped with extensive optical access for the application of advanced laser-based diagnostics, including an extended cylinder with a piston-crown window and a full transparent quartz cylinder liner. The intake air system provides intake pressures up to 2 bars and heating to 250°C. These high intake temperatures allow investigations of HCCI operation with lower compression ratios (10:1 to 12:1). The engine is equipped with a centrally mounted gasoline-type direct injector (GDI), a port-fuel injection capability, and a fully premixed fueling system, allowing investigations of both well-mixed and stratified HCCI operation. In addition, the engine is equipped with spark plugs for investigations of the transition from HCCI to SI operation.

Current experiments are using laser-induced fluorescence (LIF) imaging to understand the relation between the fuel-air-residual mixing process and subsequent emissions. Partial stratification is often proposed as a possible strategy for reducing CO emissions, and these experiments facilitate the development of such strategies. Liquid-phase LIF imaging will be used to judge the extent of wall-wetting and its impact on mixture preparation. Direct luminosity and elastic scattering images recorded during the same cycle as LIF images will allow correlation of charge preparation with combustion and with possible smoke production.

High-Speed, Small-Bore Diesel Engine Laboratory

This laboratory is set up to investigate fluid dynamics and combustion processes in compression-ignition engines for passenger vehicles. The single-cylinder, optical engine mimics the best-in-class high-speed diesel engines being introduced in the European market. This engine has a speed range of 0 to 4,000 rpm, a 4-valve head with variable swirl, a vertical central injector supplied by common rail, and a compression ratio of 19:1. A quartz piston crown machined to match current complex bowls along with cylinder-wall windows provide optical access without compromising geometric similarity. The laboratory is equipped with a full complement of engine support subsystems.

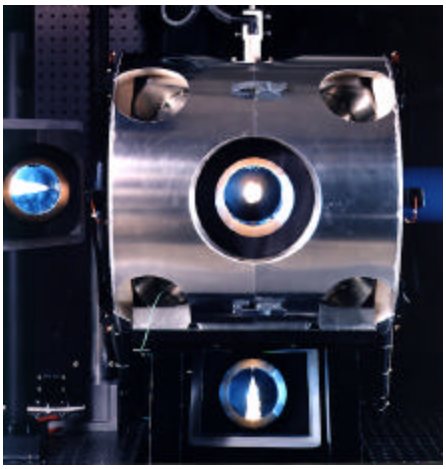


Optically Accessible
Small-Bore Diesel Engine

Researchers at Sandia are using the facility to investigate in-cylinder mixing and combustion processes unique to small-bore diesel engines. The highly swirling flows along with spray-wall and flame-wall interactions found in such engines are considerably different from those in large-bore, quiescent-chamber, heavy-duty diesel engines. The current research emphasis is on developing the physical understanding needed to expand the applicable speed/load range of low-temperature, low-emission diesel combustion regimes.

Diesel Combustion Simulation Facility

The interpretation of data from experiments conducted in diesel engines is challenging because it is difficult to independently vary the many parameters that affect in-cylinder combustion processes. In the Diesel Combustion Simulation Facility (DCSF), injector parameters and the ambient gas temperature, density, and composition can be controlled and varied in a more systematic manner, allowing the effects of these variables to be assessed independently. The capabilities of the DCSF are unique in the world and have provided significant new insights into diesel engine combustion processes. With full optical access, diesel conditions with ambient pressures as high 35 MPa, ambient temperatures between 600 and 1400 K, and ambient densities between 3.5 and 60 kg/m^3 can be simulated.



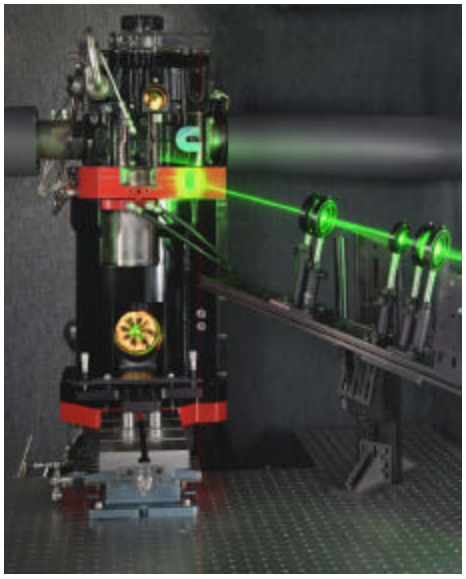
Diesel Combustion Simulation Facility

Researchers at Sandia are currently using the DCSF to study the soot processes in diesel fuel jets. Soot concentration measurements are being performed at diesel operating conditions for a wide range of ambient gas temperatures, ambient gas densities, ambient oxygen concentrations, injection pressures, injector orifice diameters, and fuel types. The data are providing an improved fundamental understanding of diesel soot formation processes. At some injec-

tor and ambient conditions, our research has shown that soot formation can be suppressed entirely in a fuel jet, even at low-flame temperature (*i.e.*, low NO_x) conditions when using a #2 diesel fuel. This has lead to a new area of investigation on low-emission, mixing-controlled diesel fuel jet combustion.

Heavy-Duty Diesel Engine Combustion Laboratory

This laboratory employs advanced optical imaging and laser diagnostics to investigate diesel spray combustion and pollutant-formation processes occurring inside an operational diesel engine. The insight gained from these investigations has been shared with U.S. manufacturers of heavy-duty diesel engines (including Detroit Diesel, Caterpillar, and Cummins) and has been used in the development of cleaner, more fuel-efficient engines.

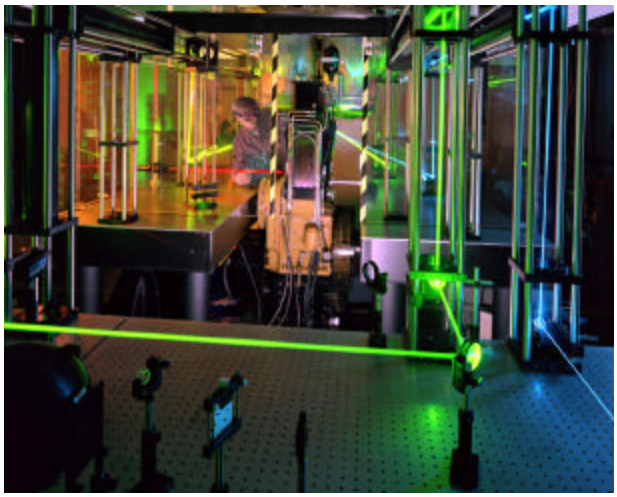


Optically Accessible
Heavy-Duty Diesel Engine

The engine in this laboratory is a 2.3-liter, single-cylinder diesel engine, which was derived from a production highway truck engine. It has been modified for optical access by placing windows in the piston crown, cylinder head, and cylinder walls. These windows provide optical access both for cameras, which record images of in-cylinder combustion, and for laser beams, which are used to probe in-cylinder processes, while the engine is running. Two high-power, pulsed Nd:YAG lasers, an optical parametric oscillator, and a dye laser are used for two-dimensional laser-sheet imaging diagnostics. The lasers and cameras can be tuned to probe and isolate the complex chemical and physical processes occurring inside the engine that eventually lead to pollutant emissions at the tailpipe. The engine hardware has been recently updated with a common-rail fuel injection system, a relatively new fuel-injection technology with advanced fuel injection capabilities. Current research directions include investigation of particulate matter and nitrogen oxides formation when using advanced combustion operating strategies, such as multiple injections and low-temperature combustion.

Non-Traditional Diesel Fuel Engine Combustion Laboratory

Research in this laboratory focuses on the effects of non-traditional diesel fuels and operating modes on diesel engine emissions and performance. State-of-the-art laser/imaging diagnostics are applied in a single-cylinder version of a Caterpillar C-10 engine that has been modified to provide extensive optical access to the combustion chamber. Details of injection, combustion, and emissions-formation processes can be directly observed. Engine-out emissions measurements help show which in-cylinder phenomena contribute most to pollutant reduction and provide a link to results from non-optical engine experiments. The fuel-injection system is capable of multiple injections with user-selected timing and is compatible with a full complement of liquid-phase fuels from biodiesel, heavy ethers, and Fischer-Tropsch diesel to gasoline and light alcohols. The engine is equipped with a glow plug to assist the ignition of low-cetane fuels. Current research activities include identifying fuel properties and in-cylinder strategies to help achieve non-sooting, low-temperature combustion.



Optically Accessible Diesel Fuels Research Engine

High-Energy Laser Diagnostics for Particulate Matter Characterization

The CRF has a record of successfully developing practical diagnostic techniques. A current national need is for diagnostic tools that can measure and characterize soot real-time in engine exhaust flows, especially at the very low soot levels characteristic of today's clean engines. In our particulate matter (PM) diagnostics work, we are developing and applying high-energy laser diagnostics for real-time measurement and characterization of PM. Diagnostics being explored include laser-induced incandescence (LII), elastic light scattering, laser-induced desorption with elastic light scattering (LIDEL's), and laser induced-breakdown spectroscopy (LIBS). A research partner, Artium Technologies, is in the final stages of developing a commercial LII instrument for measuring soot concentrations. Their LII instrument is portable, safe, rugged, reliable, and automated and offers push-button simplicity for measuring soot concentration. The LIDEL's technique under development holds promise for providing real-time soot and volatile-organic-fraction measurements. We are currently working with various industry partners, as well as Oak Ridge National Laboratory, to demonstrate and apply the LII and LIDEL's diagnostics.

PATENTS AND AWARDS

The main focus of the Engine Combustion Research Program at the CRF is on developing the science base regarding in-cylinder combustion and emissions processes. The staff's success at this is corroborated by the numbers of technical papers accepted by refereed journals, papers presented at major conferences, and awards received. Over the past 5 years, scientists in the engine combustion group have published more than 120 technical papers. Three of the staff have also been made Society of Automotive Engineers (SAE) Fellows and are recipients of the prestigious SAE Horning Award for significant contributions to the engine and fuels research fields. Two SAE Arch T. Colwell Merit Awards for technical contributions, an American Society of Mechanical Engineers Internal Combustion Engine Division best paper award, two Lloyd L. Withrow Awards for repeated excellence in presentations at SAE conferences, a U.S. Department of Energy 100 Award, as well as many other SAE awards for service and excellence in oral presentation have also recently been received.

RECENT AND ONGOING EFFORTS

The CRF Engine Combustion Research Program continues to be conducted with close interaction and in partnership with many engine manufactures. Partners now include General Motors, Ford, DaimlerChrysler, Caterpillar, Cummins, Detroit Diesel, International, Mack/Volvo, John Deere, and General Electric. Much of the current research focus is shifting toward investigating advanced, low-temperature (*e.g.*, HCCI, SCCI, MK, *etc.*) and advanced diesel combustion regimes. Potential low-temperature combustion applications (LTC) include mixed-mode combustion systems in which diesel or spark-ignited SI combustion will be used at high loads and LTC combustion at light-to-moderate loads. Mixed-mode combustion systems offer the potential for achieving high power density, as well as high efficiency and low emissions.

FOR FURTHER INFORMATION

The CRF website can be reached at http://ww.ca.sandia.gov/CRF