Lawrence Berkeley National Laboratory

Summer 1999

Environmental Energy Technologies Division News

Air Quality Advanced Technologies Building Technologies Energy Analysis Indoor Environment

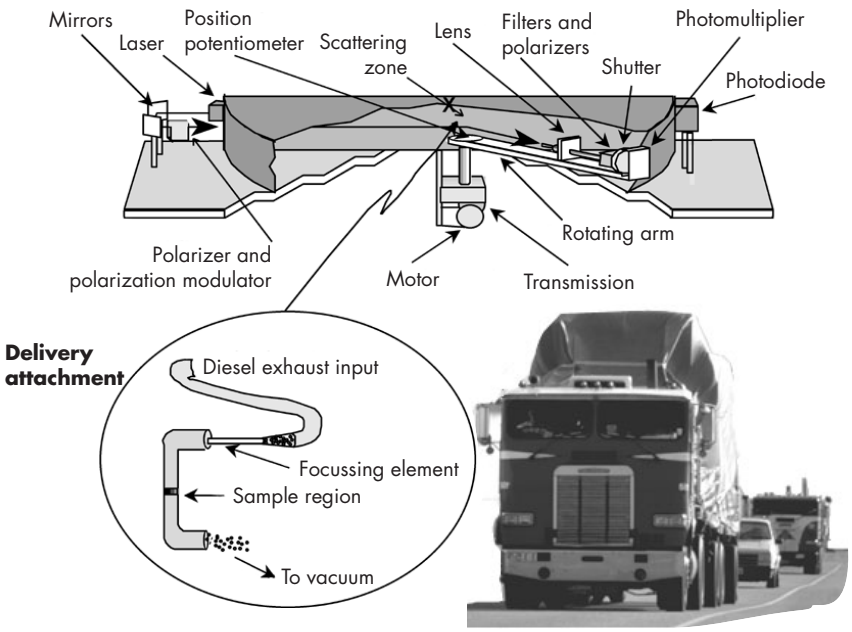
Characterizing Diesel Particle Exhaust

Premier Issue
Formerly Center for Building Science News

Recent concern about the risks to human health from airborne particulates such as those in diesel exhaust has motivated a group at the Environmental Energy Technologies Division to investigate the use of scattered polarized light. The goals are to characterize these particles and develop an instrument to measure these characteristics in real time. Having such an instrument can help regulatory authorities develop standards and monitor air quality.

Airborne particulates, especially those less than 2.5 micrometers (µm) in diameter, are known to be a major human health risk. Diesel exhaust particles are principally in this size range; they are also a major source of reduced visibility in populated areas. California recently declared particulates in diesel exhaust a hazardous material.

Current and proposed emission standards for diesel particles are based on measurements of the mass of particles emitted by a vehicle per kilometer. New particulate standards limit the total mass of particle sizes under 2.5 µm without considering size and composition. Conventional methods of measuring diesel particles have various shortcomings that can result in inaccurate data. Standard particle-collection techniques, for example, can influence the size distribution of collected particles. Instruments used to determine size distribution based on the motion of particles with respect to gases are biased toward measuring the total mass of particles collected, not the number of particles. The potential consequence of this is that a few large particles foreign to the diesel exhaust source may bias the results, obscuring the more important small-particle concentration.



A nephelometer measures the polarization of scattered light.

Light scattering is the key

To overcome the limitations associated with these techniques, we have measured light scattering from diesel particle exhaust using a well-established polarization-sensitive nephelometer, a light-scattering instrument that provides rapid, *in situ,* non-intrusive monitoring of these emissions. The technique of angle-scanning, polarization-modulation nephelometry used in our research has been demonstrated to be sensitive and diagnostic of a number of the scatterers of physical properties.

The figure shows a schematic of the nephelometer. The instrument is based on the principle that the angular dependence of the linear and circular polarization of light scattered by diesel particles depends on the size, distribution, complex refractive index,

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In this Issue

The mission of the Environmental Energy Technologies Division is to perform research and development leading to better energy technologies and market mechanisms to reduce adverse energy-related environmental impacts.

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and shape of the particles in the exhaust plume. Measuring the polarization properties of light scattered at all angles from the exhaust stream and analyzing these measurements provide information about the size distribution, complex refractive index, and shape of the particles. This information is determined from the data by simultaneously fitting the measured angular dependence of three or four scattering transformation matrix elements with Mie scattering calculations. Details of this method are available from the author.

Measurements from a simple diesel engine

Using the nephelometer, we measured the polarized light scattering of the undiluted exhaust stream from a one-cylinder, 3-kW diesel engine. Analysis of these measurements suggests that diesel particles are randomly oriented and appear spherically symmetric to light. Under no-load conditions, the engine generated small particles with a mean diameter of 0.04 µm. At full-load conditions, the particles were larger, 0.12 µm, and more absorbing. The scattering in the full-load case was characteristic of particles that are a composite of materials—probably water and soot. In the no-load case, the particles contained very little soot. The results suggest that a real-time measurement of diesel particle size distribution and shape is possible, given a minimum set of measurements taken at a number of fixed angles.

Future work

We are now working with a fully instrumented Cummins diesel engine at the University of California, Berkeley, and plan to measure exhaust from a wider variety of engine types. We are building and calibrating two real-time scatterometers dedicated to diesel measurements, one for use at Berkeley Lab/EETD and one at Oak Ridge National Laboratory. These instruments, with their rapid response times, can perform particle characterization for engine manufacturers, service facilities, and possibly emissions compliance.

—Arlon Hunt

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For a copy of "Diesel Exhaust Particle Characterization by Polarized Light Scattering," A.J. Hunt, M.S. Quinby-Hunt and I.G. Shepherd, SAE Technical Paper Series 982629, please contact the Society of Automotive Engineers (http://www.sae.org).

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Lawrence Berkeley National Laboratory

Ernest Orlando Lawrence Berkeley National Laboratory is a multiprogram national laboratory managed by the University of California for the U.S. Department of Energy. The oldest of the nine laboratories, LBNL is located in the hills above the campus of the University of California, Berkeley.

With more than 3,800 employees, LBNL's total annual budget of nearly $330 million supports a wide range of unclassified research activities in the biological, physical, computational, materials, chemical, energy, and environmental sciences. The Laboratory's role is to serve the nation and its scientific, educational, and business communities through research performed in its unique facilities, to train future scientists and engineers, and to create productive ties to industry. As a testimony to its success, LBNL has had nine Nobel laureates. EETD is one of 13 scientific divisions at Berkeley Lab, with a staff of more than 300 and a budget of $36 million.

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Miscellaneous Electricity Use

Historically, efforts to save residential energy and reduce carbon emissions in the U.S. have targeted conventional end uses such as water heating, lighting, and refrigeration. The emergence of new household appliances has transformed energy use from a few large and easily identifiable sources into a broad array of miscellaneous energy services. The miscellaneous electricity end use includes televisions and VCRs, water bed heaters, aquariums, electric toothbrushes, home computers, microwave ovens, ceiling fans, hot tubs, and halogen torchiere lamps.* This group of so-called miscellaneous appliances has been a major contributor to growth in electricity demand in the past two decades and is expected to be one of the fastest-growing residential electricity end uses in 1995 to 2010.

Based on shipments, lifetimes, and wattage data from 1976 to 1995, we constructed a bottom-up end-use model that includes more than 90 individual miscellaneous product types. We used the model to identify the most energy-consuming individual products within the miscellaneous category and identify and analyze policy priorities.

Miscellaneous electricity now accounts for approximately one-fifth of U.S. residential electricity use (235 TWh/yr). Our projections show that without policies to affect miscellaneous energy use, it will increase to 335 TWh between 1996 and 2010, accounting for almost all forecasted growth in residential electricity consumption. Product types in the consumer electronics category are expected to account for 40 percent of this anticipated growth. We also found that in some households, energy from a miscellaneous appliance can far exceed the energy from more conventional household uses. A waterbed heater can use more energy than an efficient refrigerator, and a 180-gallon coral reef aquarium tank can use more electricity than a residential central electric heating system and refrigerator combined (fortunately only about 100,000 U.S. households have such an energy-intensive aquarium).

Reducing miscellaneous consumption

Opportunities exist to reduce energy consumption in this large and quickly growing end use. Even though miscellaneous electricity is a complex end use, our results show that only ten individual product types account for more than half of current consumption. We also found that only ten product types are expected to account for 60 percent of the projected growth. About 20 percent (40 TWh/yr) of miscellaneous consumption consists of standby losses from appliances that are switched off or are not performing their principal function. These standby losses are sometimes called "leaking" electricity and mainly occur in consumer electronics.

More than $1 billion per year could be saved in the U.S. by reducing the standby power loss of every leaking appliance to one watt. These efforts would reduce standby power consumption by nearly 50 percent. Models offered by major manufacturers in most product categories now routinely meet this one-watt level for standby power, without affecting the services delivered to consumers. Ongoing voluntary labeling efforts similar to US EPA's EnergyStar® TV, VCR, and audio programs can help reduce forecasted growth in the miscellaneous electricity end use.

—Marla Sanchez

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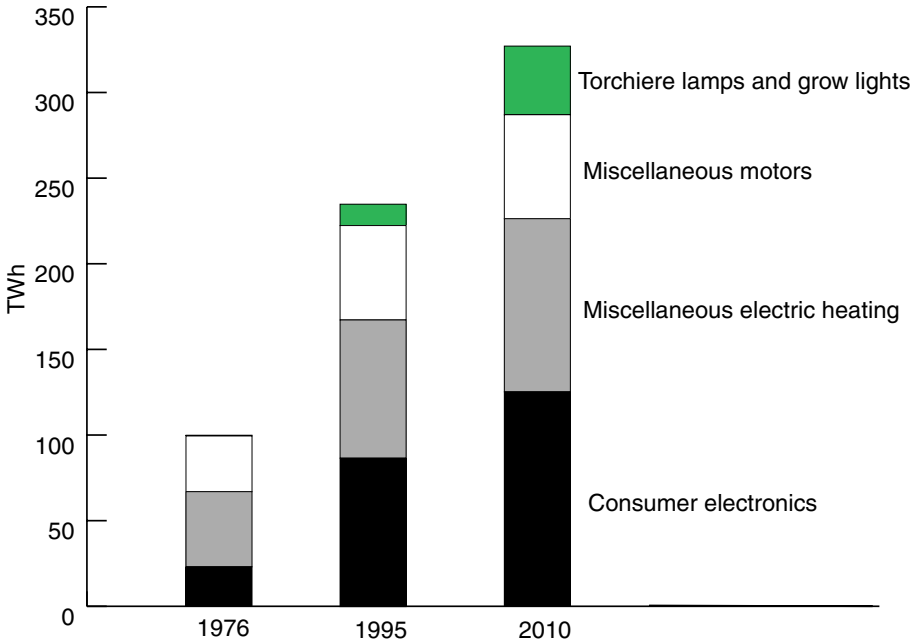
The text of the report "Miscellaneous Electricity Use in the U.S. Residential Sector," by M.C. Sanchez, J.G. Koomey, M.M. Moezzi, A.K. Meier, and W. Huber, LBNL-40295, is available for downloading at: http://enduse.lbl.gov/Projects/ResMisc.html.

For more information, refer to "Homes that leak electricity and how to plug them" at http://www.lbl.gov:80/Science-Articles/Archive/leaking-watts.html.

This research is supported by the U.S. Department of Energy's Office of Building Technologies, State and Community Programs.



Disaggregation of residential miscellaneous energy use by major end-use category.

*Data sources used in this study classified halogen torchieres as "miscellaneous" even though they represent a lighting end use.

COMIS: An Interzonal Air-Flow Model

To provide good indoor air quality and to correctly size a building's space-conditioning equipment, the designer must understand air-flow patterns. A knowledge of interzonal flows is required to determine the impact of infiltration and natural and mechanical ventilation on indoor air quality. Mathematical models can determine infiltration values for all air-leakage and weather combinations.

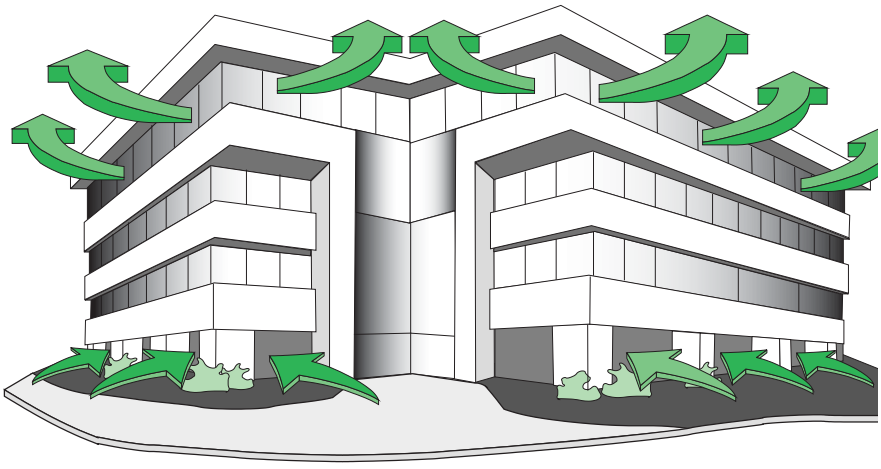
Interzonal air-flow models calculate air-flow-related energy losses and the flow distributions in buildings. These models fall into two categories: single and multizone. Single-zone models assume that a building can be described by a single well-mixed zone. They are usually used for modeling single-story, single-family houses with no internal partitions (all inside doors are open). For detailed research uses, however, most buildings should be characterized as multizone structures even when no internal partitions are present. Researchers have developed models that simulate the interzonal flows of buildings with more than one well-mixed zone.

COMIS's structure

Conjunction of Multizone Infiltration Specialists (COMIS) is a recent development in interzonal air-flow modeling, with a modular structure that helps it stimulate buildings more effectively than earlier multizone air-flow models. It can be used as a stand-alone model with input and output features, or as an air-flow module for thermal building simulation programs. It can also serve as a module library for other models.

The COMIS program was designed during a 12-month workshop at Berkeley Lab in 1988 and 1989. In 1990, the Executive Committee of the International Energy Agency's Energy Conservation in Buildings and Community Systems program created a group of experts from nine nations to continue this work. In early 1998, this group released COMIS 3.0 and a user interface designed for UNIX- and Windows-based systems, IISiBaT. More than 200 copies of the program are in use in at least 15 countries.

Modules in COMIS include air-flow equations for large vertical openings, single-sided ventilation, and different opening situations for various window constructions.



COMIS models the air flow and contaminant distributions in buildings.

Key components

COMIS models the air flow and contaminant distributions in buildings. The program can simulate several key components influencing air flow: cracks, ducts, duct fittings, fans, flow controllers, large vertical openings (windows and doors), kitchen hoods, passive stacks, and "user-defined components." COMIS allows the user to define schedules describing changes in the indoor temperature distribution, fan operation, pollutant concentration in each of the modeled zones, pollutant sources and sinks, opening of windows and doors, and weather data. The "flexible time step" implemented in COMIS enables users to model events independent of the frequency with which the weather data are provided.

The COMIS air-flow calculation is based on the assumption that indoor air flows reach steady-state at each time step. The contaminant transport is based on a dynamic model and has its own time step, based on the time constant of the most critical zone. The two models are coupled. Results for air flows and contaminant levels are reported in terms of tables by COMIS and in graphical form by some of the user interfaces.

The Environmental Energy Technologies Division is conducting several ongoing COMIS-related projects. Researchers are integrating COMIS into EnergyPlus, the next generation of thermal building simulation models under development by EETD and the University of Illinois. An aerosol deposition model for rooms and ducts is also in development, as are a room model (MIAQ4) at the University of California, Berkeley. We are planning a new module dealing with air flow through staircases and Concordia University is developing a zonal model that will also be integrated into COMIS.

COMIS and IISiBaT are available for downloading at http://www-epb.lbl.gov/comis/.

—Helmut Feustel

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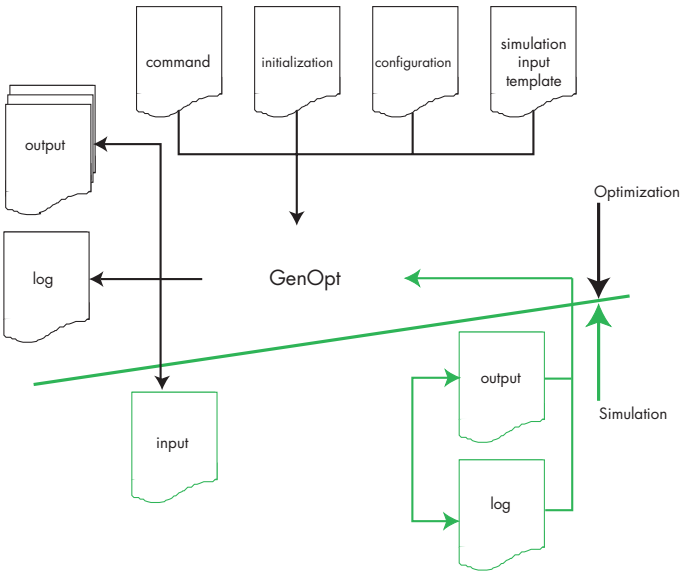
GenOpt: A Generic Optimization Program

GenOpt is a generic multiparameter program being developed for system optimization. It automatically determines the values of user-selected design parameters that lead to the best operation of a given system. It can also determine unknown parameters in a data-fitting process. GenOpt optimizes a user-selected objective function, such as a building's calculated annual energy use. It also offers an interface for easily adding users' own optimization algorithms to its library.

GenOpt is currently being developed as a console application, written entirely in Java so that it is platform-independent. The interface for coupling external simulation programs and adding custom optimization algorithms has been completed. GenOpt currently works under UNIX Solaris 2.5.1, Windows NT, and Windows 95.

Why optimize?

A lot of time is spent specifying the input for a simulation model, but once this is done, the user usually does not try to optimize it. This can be because there is no time left for the tedious process of changing input values, running the simulation, interpreting the new results, and guessing how to change the input for the next trial, or because the systems being analyzed are so complex that the user is not capable of understanding the interactions of the various parameters. GenOpt makes it possible to do automatic multiparameter optimization with search techniques that require only a little effort.



Interface of GenOpt and the simulation program.

How GenOpt works

To perform the system optimization, GenOpt automatically writes an input file. The generated input file is based on an input template written for the simulation program. GenOpt then launches the simulation, reads the value of the function being minimized from the simulation result file, checks possible simulation errors, and determines a new set of input parameters for the next run. The whole process is repeated iteratively until the minimum of the function is found. If the simulation problem has some underlying constraints, they can be taken into account either by a default implementation or by modifying the function that has to be minimized. GenOpt offers a default scheme for simple constraints on the independent variables (box-constraints), as well as a formalism that allows constraints to be added to the simulation problem by means of so-called penalty or barrier functions. For example, GenOpt could be used to find the area of the windows or facades of a house that minimizes annual energy use subject to the constraint that each area must be within user-specified minimum and maximum values.

Interface for simulation program

GenOpt has an open interface on both the simulation-program and optimization-algorithm sides. It permits the easy coupling of any external program like SPARK, DOE-2, BLAST, or a user-written program by modifying a configuration file.

The data exchange between GenOpt and the external program is done with text files only (see the figure). GenOpt automatically generates a new input file for the simulation engine based on an input template file. To generate such a template, the user accesses the already-defined simulation input file and replaces the numerical values of the parameters to be modified with keywords. GenOpt then replaces those keywords with the corresponding numerical values and writes the simulation input file. This approach makes GenOpt capable of writing text input for any simulation program. In a configuration file, the user can specify how the simulation program is to be launched and where GenOpt can find the current value of the objective function to be minimized. This makes it possible to couple any external program to GenOpt without modifying and recompiling either program. The only requirement of the external program is that it must read its input from a text file and write the function value to be minimized (plus any possible error messages) to a text file.

—Michael Wetter

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The alpha version of GenOpt is ready to be tested by a limited number of users. For further information and to register as a tester, visit the GenOpt web site at http://eetd.lbl.gov/btp/simulations.

This research is sponsored by the U.S. Department of Energy's Office of Building Technology, State and Community Programs.

News from the D.C. Office

The Lab's Washington D.C. Project Office has recently added new EETD staff and made steady progress on several projects underway with Department of Energy and Environmental Protection Agency sponsorship.

New England-based partners and allies of EPA's ENERGYSTAR® Homes Program have been receiving visits from EETD. The D.C. Project Office's Don Mauritz reports that the small scale and conservative nature of that region's homebuilding industry has made it a challenge to achieve market recognition for the program, but that momentum is building because of strong support from several utility consortia, including Vermont STAR and the New England Utility Consortium of eastern Massachusetts and Rhode Island.

An EETD team is leading a Motor Challenge Program delegation to South Africa in March that will include DOE's Paul Scheihing and Don Casada of Oak Ridge National Lab (ORNL). Aimee McKane and Riyaz Papar will conduct a two-and-a-half-day workshop on industrial motor system efficiency at the invitation of the South African Department of Minerals and Energy. As a result of a similar trip to Beijing last May, Aimee is also helping DOE organize a two-week study tour by representatives of the China Energy Conservation Investment Corporation. The visit will include training in energy-efficient motor systems at the Lab's Washington Office and at ORNL, along with several plant tours. Finally, the Compressed Air Challenge announced by DOE last year, aimed at saving energy and reducing costs through the application of best practices for compressed air systems, is holding its first five training workshops at various locations around the country in February and March. For more information, see http://www. knowpressure.org.

Two Project Office staffers are conducting interviews with large companies and small business owners to gain a better understanding of how these commercial customers view their own energy consumption and costs and their perceived ability to affect them. In contrast to the stock assumption that "more information is better," Chris Payne and Annette Hanada hope to find out what comparative information on energy use would most likely motivate and empower commercial customers to reduce their energy consumption. The interviews are scheduled in selected cities and regions, including Boston, Chicago, San Francisco, and Washington, D.C. Hanada is a doctoral candidate at George Mason University.

Project Office staff have had some success in distributing the DOE-sponsored Product Energy Efficiency Recommendations for federal purchasing. Staffer Phil Coleman has introduced the document to an interagency effort to harmonize the Guide Specifications used by most federal agencies for new construction and major building-renovation projects. These specifications are commonly incorporated by architects and engineers into design and construction bid documents. Use of the DOE efficiency recommendations will be a major departure from past practice based on minimum allowable efficiency standards such as ASHRAE 90.1.

New Staff

Building DOE partnerships with energy-intensive industries in order to increase their energy-efficiency is the work of Riyaz Papar, a registered professional engineer. He joined Aimee McKane's team in May to help support the DOE Office of Industrial Technologies' Motor Challenge Program. Riyaz will also work on similar efforts in China, South Africa, and other countries.

Now assisting EPA in the evaluating and developing the ENERGYSTAR® labeling program for consumer electronics and Home Improvement Program is Marla Sanchez.

Another new staffer, Michelle Ware, recently joined the D.C. Office staff from the American Refrigeration Institute. Michelle works with Phil Coleman in support of the Federal Energy Management Program (FEMP) "Procurement Challenge" project.

—Ned Raynolds

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Around the Division

Better and More Efficient Lighting for Post Office Workers

Working with the U.S. Postal Service, EETD researchers have developed an integrated, energy-efficient task-lighting system for individual mail-sorting stations. The new system features smaller fixtures with new optics, fluorescent lamps, and electronic ballasts mounted in a high-efficiency fixture that sends 80 percent of the light to the work surface. Each workstation is controlled by an occupancy sensor. The improved lighting system reduces lighting energy costs by 30 percent. A prototype of the system is installed in the Rodeo, California, Post Office. Based on the findings of pilot projects, the Postal Service is planning to incorporate the beneficial aspects of this project into future facility designs.

For more information, contact Michael Siminovitch (MJSiminovitch@lbl.gov, (510) 486-5863).

(Left to right) Michael Siminovitch of EETD, Berkeley Lab Director Charles Shank, and Headquarters Environmental Manager Bernie Denno of the Postal Service at the Rodeo, California, Post Office under the lighting system developed at Berkeley Lab.

Gasoline Additive Examined

EETD researcher Don Lucas participated in a recent multivolume University of California study of the gasoline additive MTBE. Along with fellow researchers Bob Sawyer and Cathy Koshland, Lucas studied the effects of MTBE on air emissions from vehicles. The study, "Health and Environmental Assessment of MTBE," was delivered to the Governor and the California legislature in November 1998. The full text and other downloadable documents pertaining to MTBE are available on the Web at http://www.tsrtp.ucdavis.edu/mtberpt/homepage.html.

For more information, contact Don Lucas (D_Lucas@lbl.gov, (510) 486-7002).

Research described on this page is sponsored by the United States Postal Service, the Federal Energy Management Program, the California Environmental Protection Agency, the California Institute for Energy Efficiency, the Department of Energy's Office of Building Technology, State and Community Programs the California Energy Commission, and the U.S. Environmental Protection Agency.

Spectrally Selective Low-E Detector Reassures Builders

With DOE and California Institute for Energy Efficiency (CIEE) co-support, researchers Dariush Arasteh, Brent Griffith, Chad Goudey, Christian Kohler, and Daniel Turner developed a prototype of a simple hand-held detector to determine the coating (none, regular low-e, or spectrally selective low-e) on a double-glazed window. An infrared light-emitting diode and phototransistor measure reflectance in the near-infrared portion of the solar spectrum (where coating technologies have significantly different reflectances, which can't be detected by the human eye). One of three LEDs then illuminates, indicating which of the coatings is present.

The detector was recently tested by consultants at ConSol Inc. of Stockton, California, who were involved in several tract developments where spectrally selective low-e windows were specified to meet the California energy code or Energy Star® homes criteria.

More information may be obtained by contacting Dariush Arasteh, (D_Arasteh@lbl.gov, (510) 486-6844).

Energy Efficiency as an Insurance Loss-Prevention Strategy

LBNL's insurance initiative has released several new reports: an inventory of energy-efficient and renewable energy technologies from nine national laboratories that help prevent insurance losses, a review of insurance industry concerns pertaining to indoor air-quality problems, a report on ultraviolet water disinfection for U.S. natural disaster recovery situations, and a case study—carried out in collaboration with Arkwright Mutual Insurance Co. and Boston Edison—of how fire safety was enhanced when halogen torchiere light fixtures were replaced with energy-efficient alternatives at Northeastern University.

For more information, contact Evan Mills (EMills@lbl.gov, (510) 486-6784, <http://eetd.lbl.gov/insurance>).

EETD Helps Puts Some Air in California's Energy Standards

EETD researchers have contributed a series of findings to the new Alternative Calculation Method (ACM) used in Title 24, California's building code. The ACM, the primary design method for new homes, allows designers trade-offs to achieve levels of energy efficiency in flexible ways.

The research shows that lower duct efficiency defaults provide incentives within the standard for designers to provide a more efficient duct system. As a result of LBNL research that measured duct-sealant longevity, the new ACM does not allow thermal distribution credit if duct tape is used as the primary sealant.

An important barrier to increased duct or envelope tightness levels had been the concern that indoor air quality could be compromised at the expense of energy efficiency. To assure minimum ventilation rates in buildings, Division researchers worked with the California Energy Commission to incorporate ASHRAE Standard 62-89 (Ventilation for Acceptable Indoor Air Quality) into the code in an energy-efficient manner.

More information can be obtained by contacting Max Sherman, (MHSherman@lbl.gov, (510) 486-4022).

A-Team Report

Pikes Peak Charrette

Pikes Peak, Colorado, has been a popular vacation destination since the late 1800s. The Summit House contains a visitors' center and other utility buildings. Built in 1964, the House is now too small to handle the one-half million visitors it receives each summer. In addition, improper thermodynamic engineering during construction has triggered a melting of the permafrost, resulting in an uneven and unpredictable sinking of the House.

To assist with planning a new Pikes Peak Summit House (shown above), teams from the Laboratory Technical Assistance Program (LabTAP) and the Federal Energy Management Program (FEMP) of the U.S. Department of Energy helped the Pikes Peak Preservation Director organize and conduct a design charrette. From March 25 to 27, 1998, participants from several national laboratories, including EETD's Applications Team, and federal and local agencies explored options regarding energy-efficient building design, on-site energy alternatives, sustainable transportation options, and water-supply and resource-efficiency issues.

Some of the high-priority recommendations brought forth include reducing heating energy use with demand-controlled systems, optimizing building-control systems (such as lighting), and developing high-R insulation systems that prevent the interior heat from being transmitted to the permafrost. Other less critical but worthwhile measures could include installing passive refrigerators that use outside air, radiant heating, and compact fluorescent lamps and photovoltaic panels.

EETD Applications Team head Dale Sartor noted that the charrette demonstrated DOE's capability to deploy a multidisciplinary team from several of its national laboratories. This can be a great help to local communities in implementing sustainable design practices.

—Ted Gartner

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Sources

EREC: Energy Efficiency and Renewable Energy Clearinghouse

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