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ENERGY DIVISION ANNUAL PROGRESS REPORT for Period Ending September 30, 1992

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ORGANIZATIONAL CHART

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ACRONYMS

ac	alternating current
ADANS	AMC Deployment Analysis System
AFEAS	Alternative Fluorocarbon Environmental Acceptability Study
AID	U.S. Agency for International Development
AMC	Army Materiel Command
ANSI	American National Standards Institute
APEC	Asia Pacific Economic Cooperation/Asia Pacific Energy Commission
ARC	Appliance Research Consortium
ARI	Air-Conditioning and Refrigeration Institute
ASTM	American Society for Testing and Materials
ATIS	Advanced Traveler Information Systems
ATMS	Advanced Traffic Management Systems
BER	Building Equipment Research (Program)
BERC	Building Envelope Research Center
BPA	Bonneville Power Administration
BTESM	Building Thermal Envelope Systems and Material (Program)
BUR	built-up roof
CAA	Clean Air Act of 1970
CAAA	Clean Air Act Amendments of 1990
CADDET	Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (IEA)
CAREIRS	Conservation and Renewable Energy Inquiry and Referral Service
CARES	Central American Rural Electrification Support
CCT	Clean Coal Technology (Program)
CDFG	California Department of Fish and Game
CFC	chlorofluorocarbon
CO	carbon monoxide
CO ₂	carbon dioxide
COM/Electric	Commonwealth Energy Systems
COP	coefficient of performance
CRADA	cooperative research and development agreement
CSDP	Chemical Stockpile Disposal Program (U.S. Army)
CSEPP	Chemical Stockpile Emergency Preparedness Program
CTA	Center for Transportation Analysis
dc	direct current
DCC	direct coupled condenser
DCE	dichloroethene
DEIS	draft environmental impact statement
DFA	Damage Function Approach
DHC/C	District Heating, Cooling, and Cogeneration (Program)
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation

DSM	demand-side management
EA	environmental assessment
EBMUD	East Bay Municipal Utilities District
EBS	Emergency Broadcast System
EC	the European Communities
EEAS	Energy and Economic Analysis Section
EER	energy-efficiency ratio
EERC	Energy, Environment, and Resources Center (UT)
EESAP	Energy Efficiency Strategy Assistance Program
EHS	external heat system
EIA	Energy Information Administration (DOE)
EIS	environmental impact statement
EMF	electromagnetic field
EPA	U.S. Environmental Protection Agency
EPDM	ethylene propylene diene monomer
EPPE	Energy Program Planning and Evaluation
EPRI	Electric Power Research Institute
ER	environmental report
ERIP	Energy-Related Inventions Program
ERRS	Efficiency and Renewables Research Section
ESRA	Envelope Systems Research Apparatus
FAST	Flow and Analysis System for Transportation (TRANSCOM)
FCC	fluid catalytic cracker
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FFE-3	third Federal Field Exercise
FHWA	Federal Highway Administration
FSU	former Soviet Union
FTC	Federal Trade Commission
FY	fiscal year
FYP	fiscal year plan
GAX	generator-absorber heat exchange
GDP	gaseous diffusion plant
GDT	geophysical diffraction tomography
GEEI	Global Energy Efficiency Initiative
GEIS	generic environmental impact statement
GIS	Geographic Information System
GPR	ground-penetrating radar
GRI	Gas Research Institute
GWh	gigawatt hours
GWP	global warming potential
HCFC	hydrochlorofluorocarbon
HEMP	high-altitude electromagnetic pulse
HFC	hydrofluorocarbon
HGP	Hawaii Geothermal Project
HPDM	heat pump design model
HUD	U.S. Department of Housing and Urban Development

HVAC(&R)	heating, ventilation, and air-conditioning (and refrigeration)
HVDC	high-voltage direct current
HX	heat exchanger
IAAS	Integrated Analysis and Assessment Section
IC	internal combustion
ICDB	Integrated Cargo Data Base
IEA	International Energy Agency
INEPCP	Institute of Energy Problems of Chemical Physics (former Soviet Union)
IRP	integrated resource planning
IVHS	Intelligent Vehicle Highway Systems
JIEE	Joint Institute of Energy and Environment
K	Kelvin
k	thermal conductivity
KCP	Kansas City Plant
kV	kilovolt
kW	kilowatt
kWh	kilowatt hour
LCUP	least cost utility planning
LMRP	Lower Mokelumne River Project
LSCS	Large Scale Climate Simulator
mpg	miles per gallon
MSW	municipal solid waste
MTMC	Military Traffic Management Command
MW	megawatt
NAHB	National Association of Home Builders
NAPAP	National Acid Precipitation Assessment Program
NARM	nonazeotropic refrigerant mixture
NAS	National Academy of Sciences
NATAS	National Appropriate Technology Assistance Service
NEAT	National Energy Audit
NEPA	National Environmental Policy Association/Act (of 1969)
NES	National Energy Strategy
NIs	Newly Independent States (of Eastern Europe)
NO _x	nitrogen oxides
NPC	National Petroleum Council
NPS	National Park Service
NPTS	National Personal Transportation Survey
NRC	Nuclear Regulatory Commission
NRCA	National Roofing Contractors Association
NSF	National Science Foundation
NTACS	Nationwide Truck Activities and Commodity Survey
NTP	National Transportation Policy
NUP	non-utility party
NWEA	National Wood Energy Association
NYSE&G	New York State Electric and Gas Corporation
ODP	ozone-depleting potential

ORNL	Oak Ridge National Laboratory
ORNL-RYM	Oak Ridge National Laboratory Refinery Yield Model
ORP	Oil Research Program
OTA	Office of Technology Assessment
PADD I	Petroleum Administration for Defense District (U.S. East Coast)
PADD III	Petroleum Administration for Defense District (U.S. Gulf Coast)
PADRE	Protective Action Dose Reduction Estimator (Model)
PC	personal computer
PEA	programmatic environmental assessment
PHA	public housing authority
PIR	polyisocyanurate
PMF	probable maximum flood
ppb	parts per billion
PUC	public utility commission
R&D	research and development
RD&D	research, development, and demonstration
RF	refrigerator/freezer
RFF	Resources for the Future
RFG	reformulated gasoline
RFP	request for proposal
ROCAP	Regional Organization for Central American Programs (AID)
RTRA	Roof Thermal Research Apparatus
RVP	Reid vapor pressure
S ₂ F ₁₀	disulphur hexafluoride
SEAB	Secretary of Energy Advisory Board (DOE)
SEER	seasonal energy-efficiency ratio
SF ₆	sulphur hexafluoride
SO _x	sulphur oxides
SPR	Strategic Petroleum Reserve
STAA	Surface Transportation Assistance Act (of 1982)
T&D	transmission and distribution
TAF	thousand acre-feet
TAHP	thermally activated heat pump
TCE	trichloroethene
TEWI	total equivalent warming impact
TIUS	Truck Inventory and Use Survey
TORIS	Tertiary Oil Recovery Information System
TRANSCOM	U.S. Transportation Command
TRB	Transportation Research Board (Committee on Traffic Flow (Theory and Characteristics)
TVA	Tennessee Valley Authority
UNEP	United Nations Environmental Program
US-AEP	U.S.-Asia Environmental Partnership
USAP	U.S. Antarctic Program
UT	University of Tennessee
VOC	volatile organic compound
WAG	waste area grouping
WAM	Waterway Analysis Model

WAP
WAPA
WTE

Weatherization Assistance Program
Western Area Power Administration
waste-to-energy

ABSTRACT

Energy Division's mission is to provide innovative solutions to energy and related issues of national and global importance through interdisciplinary research and development. Its goals and accomplishments are described in this annual progress report for FY 1992. Energy Division is committed to (1) understanding the mechanisms by which societies make choices in energy use; (2) improving society's understanding of the environmental, social, and economic implications of technological change; (3) developing and transferring energy-efficient technologies; (4) improving transportation policy and planning; (5) enhancing basic knowledge in the social sciences as related to energy and associated issues; and (6) providing a unique climate that allows engineers and physical, environmental, and social scientists to address major societal problems and to develop professionally in their respective disciplines.

Energy Division's total expenditures in FY 1992 were \$42.8 million. The work is supported by the U.S. Department of Energy, the U.S. Department of Defense, many other federal agencies, and some private organizations. Disciplines of the 116.5 technical staff members include engineering, social sciences, physical and life sciences, and mathematics and statistics.

The division's programmatic activities cover three main areas: (1) analysis and assessment, (2) energy conservation technologies, and (3) military transportation systems. Analysis and assessment activities involve energy and resource analysis, preparation of environmental assessments and impact statements, research on waste management, technology transfer, analysis of energy and environmental needs in developing countries, and civilian transportation analysis. Energy conservation technologies focus on electric power systems, building envelopes (walls, foundations, roofs, attics, and materials), and methods to improve energy efficiency in existing buildings. Military transportation systems conduct research for sponsors within the U.S. military to improve the efficiency of military deployment, scheduling, and transportation coordination.

Much of Energy Division's research is valuable to other organizations as well as to sponsors. This information is disseminated by the staff's involvement in professional and trade organizations and workshops; joint research with universities and private-sector firms; collaboration with state and local governments; presentation of work at conferences; and publication of research results in journals, reports, and conference proceedings.

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I n t r o d u c t i o n

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E x e c u t i v e

S u m m a r y

R. B. Shelton
Director

INTRODUCTION AND EXECUTIVE SUMMARY

The mission of the Energy Division is to provide innovative solutions to energy and related issues of national and global importance through interdisciplinary research and development (R&D). One of 17 research divisions at Oak Ridge National Laboratory (ORNL), Energy Division was established in 1974 to consolidate work on environmental, technological, and regional assessments related to energy development and to conduct research on improving the efficiency of energy use and conversion. The division's research activities continue to reflect these themes.

The division focuses on technology and human systems. Its research can be categorized into three major areas: analysis and assessment, energy conservation technologies, and transportation systems. Analysis and assessment includes such topics as energy and resource analysis, environmental assessments, emergency preparedness, analysis of developing countries,

technology transfer, and analysis of civilian transportation. The division's work on energy conservation technologies includes building equipment, building envelopes, electric power systems, and existing buildings. The third area includes R&D of planning models for transportation systems. While much of the work emphasizes energy and environmental issues, Energy Division also addresses other pressing issues on the national agenda, reflecting the division's problem-driven nature.

Energy Division is one of the most diverse research divisions at ORNL in terms of its sponsorship, research activities, and range of staff expertise. Division expenditures in FY 1992 totaled \$42.8 million, as shown in Fig. 1.1. Roughly 60% of the budget was provided by the U.S. Department of Energy (DOE), over 20% by the U.S. Department of Defense, and the remainder by private industries and other federal agencies. In terms of expenditures by research area

Michael Kuliasha, Associate Division Director.

(Fig. 1.2), analysis and assessment activities accounted for almost one-half of the budget, energy conservation technologies for two-fifths, and military transportation for the remainder.

In terms of personnel, 175.5 full-time-equivalent staff and 87 on-site guests contributed their talents to the division during FY 1992. Staff

members included 116.5 technical personnel (Fig. 1.3), 41 administrative personnel, and 18 technical support personnel. More than one-third of the technical staff are engineers, another one-third are social scientists, one-sixth are physical and life scientists, and the remaining portion are data systems personnel. Over 90% of the technical staff hold advanced degrees (Fig. 1.4). Over half of the staff hold doctoral degrees, over one-third hold master's degrees, and the rest hold bachelor's degrees.

Along with staff members, consultants and subcontractors also perform work for the division (Sect. 8.8), as do staff members in other ORNL divisions, including Analytical Chemistry, Applied Technology, Chemical Technology, Engineering Physics and Mathematics, Engineering Technology, Environmental Sciences, Health and Safety Research, Metals and Ceramics, and Research Reactors divisions. The list of subcontractors in Sect. 8.8 reflects the diversity of institutions that contribute to Energy Division research activities.

This report contains overviews of the division's achievements for FY 1992 (October 1, 1991–September 30, 1992), summarizing by chapter the work of different sections within the division. Chapter 2 surveys the work performed in the Integrated Analysis and Assessment Section (IAAS), headed by Bob Reed. Chapter 3 covers the work of the Energy and Economic Analysis Section (EEAS), headed by Charles Kerley. Chapter 4 describes the work of the Center for Transportation Analysis (CTA), directed by Michael Bronzini. Chapter 5 presents the work of the Efficiency and Renewables Research Section (ERRS), led by George Courville, and Chapter 6 describes the Developing Country Program, headed by Tom Wilbanks. A summary is provided below in terms of the division's three major research themes: analysis and assessment, energy conservation technologies, and transportation systems.

Johnnie Cannon, Associate Division Director.

Fig. 1.1. Fiscal year 1992 Energy Division expenditures by sponsor.

1.1 ANALYSIS AND ASSESSMENT

Analysis and assessment activities involve five major areas: (1) energy and resource analysis, (2) environmental assessments (EAs), (3) emergency preparedness, (4) developing country analysis, and (5) transportation analysis. Common to every section of the division, energy resource analysis covers a variety of topics from energy security to utility resource planning. The environmental assessment work includes prepa-

ration of formal EAs and environmental impact statements (EISs) for various sponsors, to comply with the National Environmental Policy Act. Emergency preparedness research attempts to improve society's ability to cope with natural and technological disasters. Developing country analysis addresses pressing energy and environmental issues in such countries as China and Guatemala. Finally, transportation analysis covers civilian-sector research to develop data and analytical methods for conducting policy studies for DOE and other agencies concerned with transportation. The following sections present some highlights of the year's most promising work.

1.1.1 Energy and Resource Analysis

Why have so many waste-to-energy (WTE) projects been canceled, and what does this say about the long-run viability of WTE in the United States? A study directed by Randy Curlee took an in-depth look at these questions by assessing the numerous socioeconomic factors, financial views, and processes that have played a role in community decisions regarding WTE as a component of municipal solid-waste management strategies (see Sect. 3 highlight, "Viability of Waste-to-Energy Projects").

Work continued on the DOE Fuel Cycle Project, a multiyear study that is examining the true cost to society of producing and delivering energy. Many costs, some harmful to the welfare of people (e.g., air pollution), are not reflected in the price that consumers pay for energy. The United States has

Fig. 1.2. Fiscal year 1992 Energy Division expenditures by research area.

Fig. 1.3. Energy Division technical staff for fiscal year 1992.

increasingly recognized that the lack of high-quality information on these unaccounted costs (externalities) is distorting decision making both at the federal level, in terms of allocating energy R&D budgets, and at the state public utility board level, in terms of conservation and technology choice (see Sect. 3.3.2).

In the first half of this year, the Strategic Petroleum Reserve (SPR) project focused on the benefits from increasing the SPR's drawdown and distribution capability. Two models were used to compute the expected benefits of alternative drawdown and distribution capabilities. The analysis took into account the probabilities of oil supply disruptions, the availability of other sources of supply to offset the disruption, the elasticities of oil demand, and other market parameters (see Sect. 3.3.3).

1.1.2 Environmental Assessments

A draft EIS was prepared for the Federal Energy Regulatory Commission to consider modifications to the Lower Mokelumne River Project (LMRP) that

would enhance salmon spawning and rearing habitat. The LMRP is a multipurpose, multiple-reservoir system licensed in 1981 to the East Bay Municipal Utilities District of Oakland, California (see Sect. 2.2.1).

ORNL assisted the Army in preparing an EIS that examines the potential environmental impacts of constructing and operating a facility at the Umatilla Depot Activity (UMDA), near Hermiston, Oregon, for destroying its chemical weapon inventory. UMDA is one of eight depots where the U.S. stockpile of lethal chemical munitions are stored (see Sect. 2 highlight, "Draft EIS for the Destruction of Chemical Weapons at Umatilla Depot Activity, Oregon").

An EA was prepared on the construction, use, and eventual disposal of ice wharves at McMurdo Station, one of three year-round stations in Antarctica operated by the United States. This assessment was incorporated into an Initial Environmental Evaluation published by the National Science Foundation's

Fig. 1.4. Energy Division technical staff by level of education for fiscal year 1992.

Division of Polar Programs to comply with Executive Order 12114 and the U.S. Antarctic Treaty System requirements (see Sect. 2.2.4).

Staff members prepared a draft programmatic EA for DOE that assesses the environmental issues associated with alternatives for achieving the Oil Research Program's (ORP's) goals and objectives. The major goal of the ORP is to maximize the economic producibility of U.S. oil resources (see Sect. 2.2.5).

As part of the safety analysis reports upgrade, Energy Division hydrologists participated in regional and local flood prediction for the Portsmouth and Paducah gaseous diffusion plants (GDPs). The regional flood-hazard assessment performed along the Ohio River near the Paducah GDP used deterministic, probable maximum flood methodology. Probabilistic flood prediction methodology was implemented to estimate Scioto River water surface elevations adjacent to the Portsmouth GDP. The local flood-hazard assessments for the GDPs evaluate the potential for inundation of the main process buildings from creeks, ditches, storm sewers, culverts, and roof drainage systems during an extreme storm with an approximate recurrence interval of 10,000 years (see Sect. 2.4.1).

Geologic and hydrologic methods were used to identify the three-dimensional nature of a groundwater contaminant plume in Waste Area Grouping (WAG) 1 from a single-point datum. Using a working hypothesis of stratabound groundwater flow and contaminant transport, investigators analyzed existing subsurface geologic data to predict the contaminant plume discharge location in First Creek and locations of contaminated groundwater seepage into storm drains. Results of the analysis indicate that application of the stratabound pathway hypothesis accurately predicts the plume discharge location in First Creek, which is 65° oblique to the general gradient in that portion of WAG 1 (see Sect. 2 highlight, "Migration of a Groundwater Contaminant Plume by Stratabound Flow in WAG 1 at Oak Ridge National Laboratory").

In June, a new acoustic-based data acquisition system for geophysical diffraction tomography (GDT) was taken to Israel at the request of the Israeli Minister of Science and Technology

to conduct imaging studies at archaeological sites. The most interesting of these sites is Shiqmim, located in the Northern Negev desert, where archaeologists recently discovered a subterranean complex of chambers and tunnels inhabited by a prehistoric civilization almost 6500 years ago (see Sect. 2 highlight, "Geophysical Diffraction Tomography Aids Archaeological Research in Israel").

1.1.3 Emergency Preparedness

To support the Chemical Stockpile Emergency Preparedness Program (CSEPP), ORNL continued a series of technical support studies that provide technical assistance to communities to upgrade their plans and develop more specific concept plans (see Sect. 2.3.1).

As part of this CSEPP support, ORNL developed improved technologies and system designs for issuing warnings to the public. Researchers analyzed the performance of a new tone alert radio technology in conjunction with outdoor electronic sirens. This new technology incorporates various design changes that will greatly improve the system's reliability and availability (see Sect. 2.3.2).

Researchers also developed a state-of-the-art emergency management information system using a client-server architecture. A functional prototype was tested at two Army depots, and a networked ORACLE data base and front-end were then developed and tested. The system will be ready for user testing in FY 1993 (see Sect. 2.3.2).

1.1.4 Developing Country Analysis

A biomass-to-electricity project in Yunnan Province, China, is awaiting formal approval following financial and economic analysis conducted in December 1992 with assistance from a team led by Milton Russell. This decision builds upon work initiated in 1989 and supported by ORNL staff over the last 2 years (see Sect. 3.3.1).

In a report related to Hainan, China's resource options, EEAS staff members identified a strategy that (1) provides future energy services for Hainan in the least environmentally degrad-

ENERGY DIVISION STRATEGIC PLAN

Energy Division has historically produced a long-range plan that attempts to capture major trends and opportunities in its research agenda and describe major issues facing the division. While the long-range plan identified promising new initiatives and problem areas, it stopped short of formulating goals and a course of action to achieve these goals.

Developed in a series of planning workshops, which produced the first draft of a mission and vision statement for the division as well as information on possible research initiatives, the Energy Division Strategic Plan represents a departure from prior long-range plans in that it seeks to be more action-oriented. Its fundamental goal is to identify a reasonable set of concrete actions with the intent of aggressively completing them. The plan follows a conventional strategic planning paradigm (Fig. 1.5).

Desired outcomes of this strategic planning exercise include: (1) agreement on a common vision for the division; (2) an understanding of the division's current status, including strengths, weaknesses, opportunities, and threats; (3) the formulation of a strategy for achieving this common vision; (4) an agreed-upon set of goals; and (5) a set of concrete actions to achieve these goals.

With this in mind, Energy Division has chosen to focus strategic planning efforts for the 1992-1995 planning horizon on a research

theme related to its mission and vision: *Improving U.S. Competitiveness through Innovative Solutions to Global Energy And Related Issues*. As shown in Fig. 1.6, this theme targets five research initiatives, with related actions and opportunities: environmental and waste management, developing country R&D, transportation, conservation and renewables, and advanced computing.

In formulating this strategic plan, Energy Division has considered five infrastructure issues that influence the choice of strategies to achieve the division's goals:

Empowerment—To improve productivity and quality by motivating each worker to accept responsibility for his or her work, decisions should be made at the lowest appropriate level. Workers most familiar with the process are in the best position to improve the process. Ad hoc committees have been

Fig. 1.5. Energy Division strategic planning process.

formed to develop a research agenda (including proposals) for each topical area. The research will focus on issues at the energy-environmental-economic (e^3) interface.

Organizational Structure—To improve efficiency and competitiveness, the current trend in business is toward flatter organizational structures. An organizational issue unique to Energy Division derives from the multidisciplinary nature of the division's research. The strategic plan should facilitate more overlap or collaboration between the division's four research sections.

Research Directions and Implementation—Energy Division is a bottom-up organization; its continued success is dependent on the ideas, initiative, and entrepreneurial success of many principal investigators. Although research directions are ultimately determined by sponsor needs and funding, the division can better focus marketing efforts to promote a broader perspective when viewing potential topics.

Administrative Burden Distribution—Given the public nature and corresponding accountability of most division funding and the nature of the DOE-contractor relationship, it seems unlikely that the division can do much to change the nature of this environment. However, the division can determine the most efficient means for meeting its administrative responsibilities.

Staff Development—Energy Division's people are its most important asset. The division's work is generally determined by the skills and interests of its staff. Therefore, to influence division research directions, both recruiting and development of the existing staff are key priorities.

Because planning is a continuing process involving implementation, evaluation, feedback, and revision, the strategic plan will be updated biannually. It is targeted at actions the division will take as a whole and may be supplemented with more specific plans for individual sections. ♦

ORNL-DWG 93-5955

Fig. 1.6. Energy Division theme and associated opportunities for 1992-1995 research initiatives.

ing way; (2) eliminates the need to build significant amounts of new fossil-fueled, electric generating capacity, thereby saving capital to invest in other development projects; (3) lowers the cost that Hainan households and businesses will pay to light their homes and run their industries; (4) reduces the future coal import bill; and (5) improves the prospects for export industries. The focus of this strategy is to adapt proven policies and techniques—including incentive-based conservation and efficiency for producing and using energy more efficiently—to existing conditions in Hainan (see Sect. 3.3.2).

Energy Division's Keith Kline continued his leadership of the Mayarema Biosphere Preserve Project in Guatemala. In FY 1992, the project emphasized institution-building in Guatemala, which is complicated by the need to balance environmental and development priorities in a constantly changing institutional environment (see Sect. 6.2.2).

Activity in renewable and rural energy systems continued to focus on a longstanding role as project monitor and evaluator for the Central American Rural Electrification Support Project of the U.S. Agency for International Development's Regional Office for Central America and Panama (ROCAP). With project efforts led by John Shonder, the division worked closely with ROCAP and its contractor, the National Rural Electrification Cooperative Association, to improve the project's focus and its prospects for documented positive outcomes (see Sect. 6.2.5 and Sect. 6 highlight, "Central American Rural Electrification Support Project").

1.1.5 Transportation Analysis

In FY 1992, ORNL began a concerted effort to add national rail, waterway, crude and product pipeline, and air freight transportation networks to its award-winning national highway data base, and to extend such networks into Canada and Mexico. These networks, together with the location of intermodal transfer points, create a data base that will soon be used to support the Federal Highway Administration (FHWA) and the Census Bureau in their analysis of the 1993 Commodity Transportation Survey (see Sect. 4.2.1).

FHWA has asked ORNL to revise the Transportation Research Board's (TRB's) *Special Report 165* by incorporating research performed since 1975. In doing so, ORNL will work closely with TRB's Committee on Traffic Flow Theory and Characteristics to develop the much needed revision to this widely referenced text in traffic flow theory (see Sect. 4.2.2).

In support of the DOE Office of Energy Demand Policy, Energy Division researchers used the ORNL refinery linear program to study the impacts of the Clean Air Act Amendments of 1990 on U.S. petroleum refining. In an early analysis, ORNL estimated that the total added costs for reformulated gasolines could be in the range of 5 to 8 cents per gallon, a result closely matched a year later in a major study of U.S. refining by the National Petroleum Council (see Sect. 4.2.4).

1.2 ENERGY CONSERVATION TECHNOLOGIES

Energy conservation technologies incorporate (1) building equipment, (2) building envelopes, (3) existing buildings, and (4) electric power systems. Work in the building equipment domain includes developing thermally activated heat pumps for residential and commercial applications, novel cycles, and refrigeration systems. Building envelopes research deals with energy efficiency in walls, foundations, roofs, attics, and building materials, while research on existing buildings explores technical and implementation issues for improving energy efficiency in existing structures. Electric power systems research concentrates on developing technology options for increased transmission and distribution capacity, integrating new technologies, and developing enhanced control and operation strategies for future electric power systems. The following sections summarize major research activities in this area.

1.2.1 Building Equipment

Sunpower, Inc., fabricated and performed preliminary testing of the first magnetically coupled free-piston Stirling engine/compressor.

The magnetic coupling is a low-cost alternative to the hydraulic system tested successfully in a previous hardware development program (see Sect. 5.2.1).

Work was initiated on a major cooperative research and development agreement (CRADA) with the Appliance Research Consortium (a subsidiary of the Association of Home Appliance Manufacturers) on advanced refrigerator/freezers (RFs). The goal of this research is to develop advanced technology for future RFs that will reduce energy consumption by more than 50% compared with today's products (see Sect. 5.2.3).

A new program was initiated on basic heat transfer in collaboration with the heating, ventilating, air-conditioning, and refrigerating (HVAC&R) industry through the Air-Conditioning and Refrigeration Institute. A study was undertaken to determine the impact of heat exchanger augmentation and area on HVAC&R system performance (see Sect. 5.2.3).

A CRADA was completed in 1992 with the Alternative Fluorocarbon Environmental Acceptability Study (a chemical manufacturers' consortium) to assess the global warming impact of chlorofluorocarbon (CFC) alternatives. The concept of total equivalent warming impact developed during this study has been well received and is extensively cited in recent technical literature and in United Nations Environmental Program Assessment Panel reports (see Sect. 5 highlight, "Alternative Fluorocarbon Environmental Acceptability Study").

This past fiscal year, researchers developed a CFC/HFC Ratiometer, an in-house innovation in zeotropic working fluid technology, which can quickly and easily determine the composition of a refrigerant mixture. ORNL researchers discovered that the charged particle drift velocity of a refrigerant mixture is linearly proportional to the zeotropic mixture composition. Applying this discovery, researchers invented the novel device, which won an R&D 100 Award in 1992 (see Sect. 5 highlight, "CFC/HFC Ratiometer").

Design and fabrication were completed on the superconducting pulse magnet for implementing magnetic heat pump cycle experiments. Researchers initiated preliminary steady-state, transient, and loss tests (see Sect. 5.3).

1.2.2 Building Envelopes

Field testing of non-CFC polyisocyanurate roof insulation systems has been conducted for 1300 days on the Roof Thermal Research Apparatus. This work completes the original 3-year CRADA involving the Polyisocyanurate Insulation Manufacturers Association, the National Roofing Contractors Association, the Society of the Plastics Industry, DOE, and the U.S. Environmental Protection Agency (see Sect. 5.4.1).

Large Scale Climate Simulator tests with an attic test module have demonstrated that the thermal resistance of some loose-fill fiberglass insulations can decrease by up to a factor of two in cold climates because of air circulation between the warm ceiling below the insulation and the cold attic space above. ORNL research on convective heat loss in attic insulations by Ken Wilkes and Phil Childs was selected as "One of the Year's 100 Greatest Achievements in Science and Technology" by *Popular Science* magazine (see Sect. 5.4.1).

A major effort this year focused on organizing and participating in the Fifth International Thermal Performance of the Exterior Envelopes of Buildings Conference. Jeff Christian, Building Thermal Envelope Systems and Materials Program Manager, was the conference chairman; Pat Love was conference director. Over 100 speakers presented papers at the conference (see Sect. 5.4.1).

1.2.3 Existing Buildings

Two field studies were performed with the state of Arizona to investigate retrofit measures designed to reduce cooling energy consumption and electric demand. Researchers completed a study initiated in 1991 to examine the performance of an exterior insulation retrofit on walls of eight concrete block houses. A second field test in Arizona was initiated this year to determine the extent of duct leakage and air-conditioning operation problems of residential houses in the service territory of Salt River Project. This work will also determine the degree to which duct leaks can be repaired (see Sect. 5.5).

Another project completed this year was the field test of a preliminary version of the ad-

vanced audit in North Carolina. This field test involved three groups of 40 houses: (1) a group weatherized by the current North Carolina program, (2) a group weatherized as recommended by the audit, and (3) a control group that received no weatherization. Substantial space-heating energy savings were achieved by both the advanced audit and the North Carolina program (see Sect. 5.5).

A field investigation was performed for the U.S. Air Force to determine if energy efficiency is adequately addressed in the housing community plans developed as the basis for designing a major rehabilitation project. Based on this field investigation, a new project initiated for the Air Force and DOE will provide the Air Force with three state-of-the-art technical guidebooks that will assist in meeting the goals of the National Energy Strategy to improve the energy efficiency of family housing (see Sect. 5.5).

A field study is under way on the energy-saving benefits of energy controls retrofits in the United Nations Building in Washington, D.C. The demonstration will measure energy savings for different control functions and will indicate areas where DOE involvement in energy controls might be useful (see Sect. 5.5).

1.2.4 Electric Power Systems Technology

To identify R&D opportunities for real-time control and operation of electric power systems, a workshop was held with industry on November 19–21, 1991, in Denver, Colorado. Sponsors included ORNL, the Bonneville Power Administration (BPA), and Western Area Power Administration (WAPA). More than 70 power system experts attended, representing utility companies, manufacturers, and universities. Fourteen technical papers were presented on advanced monitoring and control techniques, and four planning sessions were conducted (see Sect. 5.10.1).

To identify R&D opportunities for high-voltage dc (HVDC) technology, a workshop on HVDC transmission technology was held with industry on May 6–8, 1992, in Portland, Oregon. Sponsored by ORNL, BPA, and WAPA, the workshop brought together about 80 dc experts, representing 11 foreign countries. Eighteen utility companies sent 35 representatives, and the

world's four leading dc manufacturers had 18 experts lead a 2-hour panel session on dc technology (see Sect. 5.10.2).

ORNL continues to technically monitor the progress of DOE's high-phase-order demonstration project, conducted by the New York State Electric & Gas Corporation in Binghamton, New York. This project represents the world's first commercially operated 6-phase transmission line (see Sect. 5.10.2).

A 10-year research effort was successfully completed during FY 1992 to assess the impacts of high-altitude electromagnetic pulse (HEMP) on electric power systems. The project's scope included a review of existing HEMP coupling and interaction models, as well as development of new models pertinent to the power system analysis (see Sect. 5 highlight, "High-Altitude Electromagnetic Pulses").

As DOE's lead laboratory for the National Electromagnetic Field (EMF) Research and Communications Program, ORNL is playing a major role in developing and initiating research efforts to define goals and requirements for the National EMF Strategic Plan (see Sect. 5 highlight, "Biological Effects of Electric and Magnetic Fields").

1.2.5 Conservation Implementation

The Energy Program Planning and Evaluation Group continued assessment of the commercial impacts of DOE's Energy-Related Inventions Program, evaluated a residential weatherization program operated by BPA, initiated a comprehensive evaluation of DOE's low-income Weatherization Assistance Program, and undertook an assessment of two information services programs operated by DOE: the National Appropriate Technology Assistance Service, and the Conservation and Renewable Energy Inquiry and Referral Service (see Sect. 5.6).

ORNL assisted DOE in developing an Integrated Resource Planning (IRP) Strategic Plan, which describes a process for using IRP to support the objectives of the National Energy Strategy. Other ORNL activities built upon earlier projects. A handbook was developed to encourage common terminology and assist practitioners in evaluating demand-side management

(DSM). Studies were completed on the relative effects of DSM on prices and costs for utility services, the effects of utility DSM programs on risk, and the role of collaboratives in designing DSM programs. The group also initiated various new projects (see Sect. 5.7).

1.3 TRANSPORTATION SYSTEMS

Transportation system R&D conceptualizes new approaches to planning and executing strategic deployment of personnel and materiel. Work this year focused on the Flow and Analysis System for TRANSCOM (FAST)—a military deployment analysis tool being developed by ORNL staff to help determine transportation requirements, analyze alternate courses of action, and estimate the arrival of troops and equipment traveling by air and sea into an overseas theater of operation. FAST is sponsored by the U.S. Transportation Command, the

organization responsible for all common-carrier services in the U.S. Department of Defense (see Sect. 4.4.1).

Work also continued on the AMC Deployment Analysis System, which provides the Air Mobility Command with a variety of tools for planning and scheduling the movement of personnel and cargo around the world. One of the scheduling tools is a dynamic programming-based automated scheduler that, in less than a second, can create a detailed itinerary for a mission that will not conflict with current commitments of aircraft or ground resources (see Sect. 4 highlight, "Graphical Tools Provide Insight for Airlift Planners").

Energy Division's Intelligent Vehicle Highway Systems team is providing research and analysis support to FHWA in two primary technology clusters that deal with commuter mobility: Advanced Traffic Management Systems and Advanced Traveler Information Systems (see Sect. 4.2.2).

I n t e g r a t e d **A** n a l y s i s a n d **A** s s e s s m e n t **S** e c t i o n

R. M. Reed
Section Head

INTEGRATED ANALYSIS AND ASSESSMENT SECTION OVERVIEW

2.1 INTRODUCTION

The Integrated Analysis and Assessment Section (IAAS) conducts research in the physical and social sciences and prepares environmental assessments (EAs) and environmental impact statements (EISs) for a variety of federal agencies. Because much of the work assists those agencies in complying with the National Environmental Policy Act (NEPA), IAAS has developed special expertise in such areas as emergency preparedness; radioactive waste management, siting and characterizing geohydrologic systems for waste-disposal facilities, contaminant transport modeling in atmospheric and aqueous systems, public acceptance of hazardous technologies, institutional mechanisms for managing complex technologies, socioeconomic impacts of technological change, and global environmental decision making. The section specializes in research and applied work in

these and related areas, both independently and in collaboration with other divisions at Oak Ridge National Laboratory (ORNL).

2.2 NEPA PROJECTS

IAAS plays a lead role at ORNL in preparing EAs and EISs for the U.S. Department of Energy (DOE) and other federal agency sponsors. The section provides overall project management in preparing these NEPA documents and also contributes technical expertise in such areas as air quality, meteorology, geology, surface water and groundwater hydrology, and socio-economics. This multidisciplinary work is performed by technical teams drawn primarily from IAAS; other Energy Division sections; Environmental Sciences Division; Health and Safety Research Division; other ORNL divisions such as Chemical Technology, Engineering Technology, and Research Reactors; and subcontractors.

ORNL-Photo 874-93

Hawaii Geothermal Project researchers survey the Hawaiian landscape (IAAS group leader Chuck Boston is third from left).

The section prepares NEPA documentation for a number of federal sponsors, including DOE, the Nuclear Regulatory Commission (NRC), the Army, the Air Force, the Federal Energy Regulatory Commission (FERC), the National Science Foundation (NSF), and the National Park Service (NPS). The scope of these NEPA projects ranges from large complex projects and programs to very narrowly defined actions at specific sites. Table 2.1 provides a partial listing of NEPA projects under preparation in FY 1992.

During FY 1992, IAAS continued to support several major NEPA programs, including the Army's Chemical Stockpile Disposal Program (CSDP), DOE's Clean Coal Technology (CCT) Program, and NSF's U.S. Antarctic Program. An overview of the CSDP program is provided in Sect. 2.2.3. The Supplemental EIS prepared by ORNL on the U.S. Antarctic Program was published by NSF in October 1991, and ORNL staff continued to support the Division of Polar Programs in developing EA documentation.

IAAS staff members participated in a public workshop during the comment period on the

NRC Draft Generic EIS (GEIS) on license renewal for commercial nuclear power plants in the United States. Most support to this NRC project has focused on developing responses to public comments. ORNL will assist NRC in preparing a final GEIS in FY 1993 to address public comments and major policy issues raised during the comment period.

Two Environmental Reports (ERs) were

completed this year that contain extensive data and analyses to assist respective sponsors in preparing EISs. An ER was delivered to DOE on the Advanced Neutron Source project, which may be built at ORNL. A second ER was prepared for NPS on a proposed 10 mile extension of the Foothills Parkway between Wear Valley and Pigeon Forge, Tennessee. This report compiles data on extensive field studies conducted by IAAS and subcontractor staff of the potentially affected environment, analyzes impacts that would result from construction and use of the parkway, and recommends methods for mitigating predicted impacts.

IAAS support for FERC included preparing two EAs that evaluated the potential cumulative environmental impacts from hydroelectric development in the Skagit and Nooksack river basins in Washington State. These EAs identified projects that could result in significant cumulative environmental impacts. On the basis of the findings in these EAs, FERC asked ORNL to prepare two EISs on hydropower projects in the Skagit and Nooksack river basins with the potential to cumulatively impact the environment.

Table 2.1. Partial listing of FY 1992 National Environmental Policy Act projects

Project	Sponsor ^a
Environmental Assessments	
Kelly Air Force Base munitions loading activity	USAF
Kelly Air Force Base industrial waste collection system	USAF
Kelly Air Force Base central staging area	USAF
Proposed C-17 facilities at Kelly Air Force Base	USAF
Sale of Parcel A to the city of Oak Ridge	DOE
Melton Valley liquid low-level waste system upgrade	DOE
Contact-handled and remote-handled transuranic waste facilities at Oak Ridge National Laboratory	DOE
Oil Research Program	DOE
Integrated gasification, combined-cycle Clean Coal Project	DOE
Olson Creek hydroelectric project	FERC
Bear Creek hydroelectric project	FERC
Skagit River hydroelectric project	FERC
Environmental Impact Statements	
Des Moines Energy Center Clean Coal Project	DOE
Hawaii Geothermal Project	DOE
Healy Clean Coal Demonstration Project in Alaska	DOE
Residue Elimination Project, Rocky Flats, Colorado	DOE
License renewal of nuclear power plants	NRC
Modifications to the Lower Mokelumne River Project	FERC
Hydroelectric projects in the Nooksack River Basin, Washington	FERC
Hydroelectric projects in the Skagit River Basin, Washington	FERC
Disposal of chemical agents and munitions stored at Pine Bluff Arsenal	Army
Disposal of chemical agents and munitions stored at Umatilla Army Depot	Army
Cryofracture facility for disposal of chemical weapons	Army
Environmental Reports	
Construction, use, and eventual disposal of ice wharves at McMurdo Station	NSF
Construction and use of blue-ice runways to support activities of the U.S. Antarctic Program	NSF
Cultural resources survey for Eldorado Air Force Station	USAF
Phase I Report for Lexington-Blue Grass Army Depot	Army
Phase I Report for Aberdeen Proving Ground	Army
Phase I Report for Pueblo Depot Activity	Army
Phase I Report for Newport Army Ammunition Plant	Army
Advanced Neutron Source Facility, Oak Ridge, Tennessee	DOE

^aNames of sponsors are abbreviated as follows: USAF indicates U.S. Air Force; DOE, U.S. Department of Energy; FERC, Federal Energy Regulatory Commission; NRC, Nuclear Regulatory Commission; and NSF, National Science Foundation.

THE GENERIC ENVIRONMENTAL IMPACT STATEMENT FOR LICENSE RENEWAL OF NUCLEAR POWER PLANTS

Although the Nuclear Regulatory Commission (NRC) grants operating licenses for commercial nuclear power plants, the Atomic Energy Act of 1954 limits the duration of these licenses to a maximum of 40 years, with provisions for license renewals. By 2020, more than half of the 118 nuclear power plants (at 74 sites) expected to have operating licenses (Fig. 2.1) will have reached the end of the original 40-year term; NRC anticipates receiving applications for the renewal of a significant number of these licenses.

Therefore, NRC has proposed license renewal rules in 10 CFR 54, and a 1500-page Draft Generic Environmental Impact Statement (GEIS) was prepared by a 25-member ORNL team. The Draft GEIS examines the potential environmental impacts of license renewal by establishing the boundaries and significance of these impacts. Conclusions reached in the Draft GEIS were placed in a framework of three categories:

1. A generic conclusion on the impact was reached for all affected nuclear power plants.
2. A generic conclusion on the impact was reached for affected nuclear power plants that fall within defined bounds.
3. A generic conclusion on the impact was not reached for any nuclear power plant.

NRC proposes to limit the scope of environmental review in individual license-renewal cases to impacts for which no generic conclusion could be reached. Of the

104 conclusions reached in the Draft GEIS, 22 fall in category 2, and 2 fall in category 3.

The Draft GEIS was issued for public comment late in fiscal year 1991. Much of the work during this fiscal year involved responding to those comments. Staff members also organized and conducted a workshop held by NRC to discuss the findings of the Draft GEIS.

Analyses in the Draft GEIS held up very well during the comment period. Utilities have argued consistently that few environmental impacts need to be considered during license renewal. State and federal agencies generally argued against reaching generic conclusions. NRC is investigating ways to resolve this conflict in light of the analyses prepared by ORNL staff. ♦

ORNL-Photo 2030-93

Fig. 2.1. License renewal for commercial nuclear power plants, such as the Watts Bar Station pictured above, could extend the license term for an additional 20 years beyond the original 40-year license.

ORNL delivered preliminary drafts of these EISs to FERC and the U.S. Forest Service (a cooperating agency) for review and comment. During the year, ORNL staff members prepared an important Draft EIS on the Lower Mokelumne Project. This EIS has since been distributed for public comment (see Sect. 2.2.1).

Throughout FY 1992, IAAS continued initial analyses that will lead to an EIS for the proposed Hawaii Geothermal Project (HGP). When first proposed, this complex project was envisioned as one alternative for reducing Hawaii's 90% dependence on imported oil for electricity generation. This original plan consisted of four phases: (1) exploration and testing of the geothermal resource beneath the slopes of the active Kilauea volcano on the island of Hawaii (the Big Island); (2) demonstration of deep-water power cable technology in the Alenuihaha Channel between the Big Island and Maui; (3) verification and characterization of the geothermal resource on the Big Island; and (4) construction and operation of commercial geothermal power-production facilities on the Big Island, with overland and submarine transmission of 500 MW of electricity from the Big Island to Oahu and possibly to other islands. The HGP EIS will assess the potential impacts of phases 3 and 4 as well as reasonably foreseeable alternatives to the project.

Several challenging and controversial issues associated with HGP have been identified during this preliminary work for the EIS. These issues include the potential for impacts to Native Hawaiian cultural and religious resources, construction of power generation and transmission facilities in a rain forest, construction and operation of facilities in a seismically and volcanically active area, and human health effects from the hydrogen sulfide emitted from geothermal wells.

ORNL provided technical assistance to the DOE Oak Ridge Field Office in preparing a siting proposal for the Nuclear Weapons Complex Reconfiguration (Complex 21). IAAS led a multidisciplinary team in preparing Volume 4 of the proposal, which considered environment, safety, and health issues related to siting Complex 21 on the Oak Ridge Reservation. This work received an "Operations and Support Award" at Martin Marietta Energy Systems Awards Night.

This year, the section is attempting to develop a more coordinated approach to preparing EAs on specific projects at ORNL and at other facilities in Oak Ridge operated by Martin Marietta Energy Systems, Inc., to address concerns that many of the evaluated actions are connected and thus can potentially contribute to cumulative impacts. Because a site-wide assessment of impacts has not been conducted for the Oak Ridge facilities, each project must address separately the potential for cumulative impacts. One approach is to develop a site-wide and current data base of potentially affected resources and impacts and to identify related actions that could contribute to cumulative impacts. By working closely with project planners, IAAS researchers hope to identify site-wide data needs early and possibly address several related actions in the same EA, thereby reducing the possibilities of delay and improving process efficiency.

The following sections describe some of the NEPA projects that IAAS staff members have worked on during FY 1992.

2.2.1 Lower Mokelumne River Project

A multidisciplinary team from the Environmental Sciences and Energy divisions prepared a draft environmental impact statement (DEIS) for FERC that considers modifications to the Lower Mokelumne River Project (LMRP) that would enhance salmon spawning and rearing habitat. This project is a multipurpose, multiple-reservoir system licensed in 1981 to the East Bay Municipal Utilities District (EBMUD) of Oakland, California. In addition to producing hydroelectricity, the project supplies almost all of the drinking water for the East Bay service area (1.1 million people) (Fig. 2.2). Facilities include Pardee Dam and Reservoir (constructed in 1929), Camanche Dam and Reservoir (constructed in 1964), the Mokelumne aqueducts, and a series of terminal storage reservoirs in the East Bay area. An abandoned copper and zinc mine, Penn Mine, is also located on the edge of the LMRP boundary on the southeast shore of Camanche Reservoir.

Chinook salmon and steelhead trout in the lower Mokelumne River have experienced re-

Fig. 2.2. Principal facilities of the Lower Mokelumne River Project, including the service area of East Bay Municipal Utilities District (EBMUD).

cent population declines and fish kills associated partly with discharges from Camanche Dam. Other stresses, such as irrigation diversions and acid mine drainage, have been affecting the fishery resources in the lower river for much of the 1900s. FERC will prescribe releases from the project and will order project modifications, as necessary, for conservation and development of the area's fish and wildlife resources.

Generally, the DEIS considers three alternatives, one proposed by the California Department of Fish and Game (CDFG), another by EBMUD, and a third by ORNL/FERC staff. Each alternative is designed to improve flow conditions for naturally spawning salmon and trout in the lower Mokelumne River, even during drought conditions. The analysis evaluates each alternative in terms of (1) the benefits that would accrue to anadromous fishery resources in the lower Mokelumne River and (2) the costs each action would impose on EBMUD's water supply system.

Each of the three alternatives would result in a water supply deficit to EBMUD during drought conditions. Under a worst-case, 3-year drought, the CDFG minimum flows would produce a supply deficit of approximately 123 thou-

sand acre-ft (TAF)/year, with an annual replacement cost to EBMUD of \$20 million. In comparison, EBMUD's minimum flows would produce a worst-case deficit of 71 TAF/year and a replacement cost of \$11.9 million. DEIS-recommended minimum flows would produce a worst-case deficit of 95 TAF/year and a replacement cost of \$15.1 million. All of these flows, however, would produce significant increases in available habitat for chinook salmon and steelhead trout in the natural stream channel of the lower Mokelumne.

On the basis of the DEIS analyses, the staff recommended a combination of flow and nonflow modifications to the existing license, including new requirements on minimum flow and minimum pool elevation at Camanche Reservoir, ramping rates on dam releases, experimental attraction and outmigrant spike flows, improvements to instream habitat, and a series of studies and monitoring to determine feasible means for solving off-site fish passage problems.

2.2.2 Kansas City Plant

As part of an overall program to help DOE evaluate the environmental impacts of operating their facilities, IAAS researchers are assessing the impacts of remedial actions at the Kansas City Plant (KCP) in Kansas City, Missouri. Originally built in 1942 to manufacture airplane engines, KCP now produces electrical and mechanical weapon components. Past activities have resulted in groundwater contamination with organic solvents such as trichloroethene (TCE) and its degradation products. Twenty-seven sites within the 137-acre (55-ha) complex are under investigation.

The greatest assessment challenge in this project involved predicting the amounts and

timing of solvent discharge via groundwater to surface waters. In the late 1980s, a groundwater contaminant interceptor well system was installed to pump and treat contaminated groundwater, impede contaminant discharge to surface water, and reduce off-site contamination. Using an existing groundwater-flow computer model, the assessment modeled solute transport. The model was calibrated using (1) the existing known groundwater contaminant plume configuration, (2) the rate of contaminant recovery from water pumped from interceptor wells, and (3) contaminant concentrations at known or suspected contaminant source areas. Analysis results confirmed that the interceptor system effectively halts groundwater contaminant discharge to surface waters (Fig. 2.3).

Using data on biotoxicity testing with *Ceriodaphnia*, a small toxicant-sensitive freshwater organism, researchers determined that the groundwater contaminant discharge to the surface waters was not toxic. In fact, TCE and its

most common degradation product, dichloroethene (DCE), were tolerated without adverse effect at concentrations ten times greater than those found in the groundwater wells nearest the streams immediately adjacent to KCP. Further alleviating conditions for the contaminated groundwater upon entry into adjacent streams include a 1000× dilution factor, microbial degradation, volatilization, and photolysis. All of these conditions contributed to the assessment finding that no ecologically significant impact would be expected on the aquatic biota at present groundwater contaminant concentrations or even at concentrations 10,000 times greater than current levels. On the basis of the computer model, projecting for 20 years, no ecologically significant impact is anticipated for the stream biota from the TCE and DCE groundwater contamination, even if no further groundwater treatment occurred.

The model also helped determine that discontinuing operation of the interceptor system

Fig. 2.3. The plume configuration of total volatile organic compounds (VOCs) at the end of 20 years of pump and treatment of groundwater at the U.S. Department of Energy Kansas City Plant, Kansas City, Missouri.

would not result in contaminant concentrations in surface water sufficient to result in any other significant, off-site environmental impacts, including impacts to human health.

2.2.3 U.S. Army's Chemical Stockpile Disposal Program

Under a mandate from Congress and in agreement with international disarmament treaties, the U.S. Army has been directed to destroy the entire U.S. stockpile of lethal unitary chemical munitions (i.e., those filled with nerve gas or blister agents). This chemical weapon stockpile is currently stored at eight Army depots in the continental United States (Fig. 2.4) and on Johnston Island in the Pacific Ocean.

In 1988, the Army issued a Programmatic EIS, prepared with the assistance of IAAS staff, that evaluated disposing of chemical weapons at the existing storage locations or transporting the weapons to regional or national disposal centers for destruction. The Army used this Programmatic EIS in formulating its decision to destroy the stockpile with a munition disassembly process followed by on-site incineration of the chemical agents and all associated munition parts—including the explosive components.

ORNL is currently assisting the Army in conducting environmental analyses for eight site-specific EISs—one for each of the eight storage depots. Each site-specific EIS will exam-

ine the potential environmental impacts of constructing and operating a facility to destroy a particular depot's chemical weapon inventory (see highlight, "Draft EIS for the Destruction of Chemical Weapons at Umatilla Depot Activity, Oregon").

One unique aspect of this work is the preparation of a Phase I Environmental Report, which is a Congressionally directed prerequisite to the preparation of each site-specific EIS. These Phase I reports will reexamine the findings and conclusions in the 1988 Programmatic EIS for the CSDP. This process includes collection of newer and more detailed site-specific data than those contained in the Programmatic EIS.

In FY 1992, the Army asked ORNL to expand the scope of the Phase I Report by including assessments of recent developments related to four areas of public concern: (1) progress in demonstrating the proposed incineration technology at the Army's Johnston Island chemical agent disposal facility; (2) advancements in alternate, nonincineration disposal technologies; (3) the successful removal and transportation of U.S.-owned chemical weapons from Europe in 1990; and (4) enhancements made to emergency preparedness capabilities around each depot. Because new findings in any one of these areas can potentially alter conclusions in the Programmatic EIS, the Phase I process is an important step in defining the scope and focus of each site-specific EIS.

Fig. 2.4. The eight U.S. Army depots serving as storage sites for chemical weapons.

Through the end of FY 1992, ORNL has completed four Phase I reports and two site-specific EISs (Table 2.2). The Phase I findings for the Tooele Army Depot in Utah and the Anniston Army Depot in Alabama agreed with the conclusions of the 1988 Programmatic EIS, thus verifying the Army's previous decision favoring on-site incineration. The Phase I process for those two depots allowed the subsequent site-specific

Table 2.2. Status of Oak Ridge National Laboratory's effort to provide environmental documentation for the U.S. Army's Chemical Stockpile Disposal Program (CSDP)^a

Environmental document	Status
(1) Programmatic Environmental Impact Statement (EIS) for the CSDP	The Final EIS was completed in December 1987
(2) EIS for Tooele Army Depot, Utah	The Phase I Environmental Report was completed in September 1988; the Final EIS, in July 1989
(3) EIS for Anniston Army Depot, Alabama	The Phase I Report was completed in July 1989; the Final EIS, in May 1991
(4) EIS for Umatilla Depot Activity, Oregon	The Phase I Report was completed in February 1990; the Draft EIS, in October 1991
(5) EIS for Pine Bluff Arsenal, Arkansas	The Phase I Report was completed in May 1990; the Draft EIS is under development

^aPhase I reports are under development for Pueblo Depot Activity, Aberdeen Proving Ground, Lexington-Blue Grass Army Depot, and Newport Army Ammunition Plant.

EISs to focus on implementation of the proposed disposal process. The other two final Phase I reports (for Umatilla Depot Activity and Pine Bluff Arsenal) also confirmed that on-site incineration is no more risky than the other disposal alternatives and is therefore worthy of implementation at those depots.

2.2.4 Ice Wharves at McMurdo Station, Antarctica

Since 1988, ORNL has provided technical assistance to NSF in preparing EAs on U.S. Antarctic Program (USAP) activities. For the most part a pristine continent, Antarctica is the focus of research for at least 26 nations. USAP supports almost 400 projects, including topics on seal physiology, testing of Mars vehicles, and investigation of the hole in the ozone layer. The remote location magnifies research problems, and solutions often require the coordinated efforts of many disciplines. In FY 1992, IAAS staff members prepared an EA on construction activities associated with replacement of ice wharves at McMurdo Station, one of three year-round stations in Antarctica operated by the United States. McMurdo Station is a major base, providing logistics support to numerous scientific field camps and the South Pole Station each austral

summer. The USAP EA was used by NSF to prepare an Initial Environmental Evaluation in compliance with Executive Order 12114 and the U.S. Antarctic Treaty System requirements.

Docking, loading, and off-loading ships at McMurdo Station require a large stable platform capable of supporting heavy equipment and cargo and providing a safe working environment (Fig. 2.5). When McMurdo Station was first built during the International Geophysical Year in 1957, cargo was off-loaded directly onto the annual sea ice about 10 km (6 miles) from McMurdo Station and then hauled by sled train to Ross Island. As the program developed, a natural wharf of shore ice in Winter Quarters Bay was used to avoid the many hazards of transporting cargo across the sea ice. Once this natural wharf deteriorated, it was replaced by a steel and wood dock structure. In 1972, the first ice dock was built, and since that time, large floating ice wharves have been built, periodically repaired, and replaced as they deteriorated.

ORNL was asked to evaluate the potential environmental impacts that could result from (1) periodic construction activities associated with replacement of ice wharves during the winter season, (2) use and maintenance of ice wharves during the annual off-loading of cargo

Fig. 2.5. The annual fuel resupply vessel is docked at the ice pier at McMurdo Station, Antarctica. The ice pier is covered with a layer of dark volcanic soil collected locally. Anchored in the background is the *Polar Star*, the U.S. Coast Guard ice breaker that prepared the way for the tanker.

ships and tankers, and (3) eventual disposal of the ice wharves. This task also included evaluating an alternative of replacing the ice wharf with a relatively permanent structure, consisting of one or more steel barges, that would be towed to McMurdo and located at the site of the previous ice wharves in Winter Quarters Bay.

Construction of an ice wharf begins when the sea ice reaches 61 cm (2 ft) in thickness. A snow berm is constructed along the perimeter of the 30,000-m² wharf to a depth of about 30 to 60 cm to contain water that is pumped onto the ice. The wharf surface is then flooded with about 10 cm of water, which freezes in about 24 hours, allowing another 10-cm layer to be added. When the wharf surface reaches 1.5 m in thickness, reinforcing steel cable is woven around a series of steel pipes to form a grid over the surface. Continued flooding allows the ice to build up for another 1.5 m, at which point a second layer of cable is added. A third layer is added when the ice is 4.6 m thick. The finished thickness of the wharf is between 6.1 and 6.7 m. Before the wharf is used each season, a 15- to 20-cm layer of very small gravel (friable pumice), taken from a borrow area, is applied to the surface. Although this material is scraped from the wharf

surface at the end of each year and stockpiled for reuse, a considerable quantity becomes embedded in the ice structure and cannot be recovered. During construction, maintenance, and use, an ice wharf may become contaminated with minor spills of petroleum products from the operation of heavy equipment and the transfer of fuel from the tanker.

Although the surface material generally absorbs such spills and is cleaned up to the extent feasible and drummed for retrograde, some residual contamination can be retained in the ice structure. When the ice wharf reaches the end of its useful life, it is towed about 25 km (16 miles) to sea and released to melt with the annual sea ice. The wharf must be removed because its presence would prevent another wharf from being built and would be an obstacle to ship movements. Before a wharf is towed out to sea, all surfacing materials are scraped off, and all structures that can be detached are removed. Environmental impacts of disposal of the wharf are considered to be minor because they occur very gradually, and the resulting contamination levels, if any, are very small.

The assessment found that construction activities associated with replacement of ice wharves would not cause any new adverse impacts. The assessment also found that using a steel barge (or barges) to replace the ice wharves has many potential advantages, including a 30-year or longer life and elimination of construction activities currently required each winter season for the ice wharves. Some dredging most likely would be required to moor the barges to

DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE DESTRUCTION OF CHEMICAL WEAPONS AT UMATILLA DEPOT ACTIVITY, OREGON

The Umatilla Depot Activity (UMDA), near Hermiston, Oregon, is one of eight depots where lethal unitary chemical munitions and chemical agents are stored (11.6%, by weight, of the U.S. total) and where the Army proposes to conduct disposal activities. Oak Ridge National Laboratory has assisted the Army in preparing an Environmental Impact Statement (EIS) that examines the potential environmental impacts of constructing and operating a facility at UMDA to destroy its chemical weapon inventory.

The disposal technology to be used at UMDA involves a munition disassembly process followed by incineration of the chemical agents and all associated munition parts—including explosive components. Analyses in the EIS focused on potential environmental impacts and socioeconomic effects associated with construction and disposal activities. For comparison, the assessment also included continued storage of the UMDA inventory.

Both routine disposal operations and hypothetical accidents were included in the analyses; however, the potential impacts from routine disposal operations were found to be minimal. Atmospheric dispersion of accidentally released chemical agents was modeled to determine the extent of the downwind hazard and to provide a basis for impact

assessment. The findings from a probabilistic risk assessment were used to address the potential human health impacts from accidental releases of chemical agent. The analyses revealed that the risks of accidents during continued storage at UMDA were far greater than risks during the proposed disposal operations. In addition, the environmental impacts would also be greater, both in extent and magnitude, for continued storage of the UMDA inventory.

Four alternative locations for the proposed disposal facility were identified within the UMDA installation. Figure 2.6 shows the results of risk calculations for transporting the munitions and disposing of them at each of the four sites. The heights of the bars repre-

Fig. 2.6. Comparison of disposal risks at four potential sites within the boundaries of the Umatilla Depot Activity (UMDA). "Expected fatalities" is defined as the product of an accident's probability and its consequences summed for all credible accidents. The risk value for UMDA is used to define 100% for Site A.

sent a measure of risk called "expected fatalities," the mathematical product of the probabilities of hypothetical accidents and their consequences (i.e., potential fatalities) during disposal activities. Sites A and B are both

preferable to sites C or D, although the difference in risk between Site A and Site B is not significant.

The Draft EIS was issued in October 1991. The Final EIS is under development. ♦

the shore at Winter Quarters Bay, resulting in adverse environmental impacts by releasing contaminated materials (e.g., polychlorinated biphenyls and residual petroleum products) from the substrate and disturbing or destroying unique bottom communities. The barge's tanks would need to be ballasted each year to limit potential damage from freezing and ice. If diesel fuel could be used to ballast these tanks, the barge would represent an additional fuel-storage facility; however, a risk analysis of the potential for the ballast tanks to leak fuel would be required before this option was pursued.

2.2.5 Assessment of DOE's Oil Research Program

IAAS staff members prepared a draft programmatic environmental assessment (PEA) for DOE that assessed the environmental issues associated with alternatives for achieving the Oil Research Program's (ORP's) goals and objectives. Because the U.S. economy is strongly dependent on oil, the goal of the ORP is to maximize the economic producibility of the U.S. oil resource. The United States has produced more oil than any other nation in history, but twice as much oil as has been produced still remains unrecovered in known reservoirs (340 billion barrels). However, U.S. proven reserves and production have declined as oil wells have been abandoned since 1970, while imports have risen dramatically because of the lack of commercially proven, cost-effective technologies to recover the remaining, known oil under present economic conditions. An attractive consideration is to tap into these reservoirs to recover as much as 76 billion barrels using technologies that could be developed and commercially applied within the next decade. The

ORP is expected to implement a research, development, and demonstration (RD&D) program in collaboration with industry, the states, and the academic community to increase oil producibility by using technically and economically superior technologies.

Several terms are used to describe the technologies involved with the ORP. These include advanced oil recovery, enhanced oil recovery, and unrecovered mobile oil. Advanced oil recovery encompasses any technology that results in oil production that is incremental over that which can be produced from a petroleum reservoir by primary and conventional secondary methods (Fig. 2.7).

The proposed action being considered by DOE is to provide cost-shared funding to implement RD&D of advanced oil recovery technologies (in collaboration with the states, industry,

Fig. 2.7. Technologies associated with advanced oil recovery (AOR) programs.

and the academic community) under the proposed ORP. The intended indirect impact of the ORP would be widespread commercialization by the oil industry of the successfully demonstrated technologies. The PEA addresses the environmental consequences of widespread commercialization of these technologies in the year 2010. The results are presented in the form of comparisons to base-line predictions for the no-action alternative in the year 2010.

The analytical approach used in the PEA is both conservative and generic. For each technology, the PEA analyzes environmental parameters of concern and their predicted impacts on the environment, including groundwater, surface water, air quality, land use, terrestrial and aquatic habitat, endangered and threatened species, socioeconomic resources, and human health and safety.

The analysis of environmental impacts is based partly on information developed from an integrated system of data bases and analytical models known as the Tertiary Oil Recovery Information System (TORIS), which estimates the potential for enhanced oil recovery from known reservoirs in the United States. DOE enhancements to TORIS allow the analysis to include both mobile and immobile oil. TORIS uses reservoir data bases composed of individual reservoirs and engineering and economic evaluation methods to predict oil recovery and project economics for various recovery technologies and crude-oil price scenarios.

The analyses found no major environmental impacts associated with commercialization of advanced oil recovery technologies. Overall, the expected percentage increase in U.S. oil production is so small (4%) that the level of impacts would be indistinguishable from the existing level. The change in level of impacts from existing conditions would be even smaller before 2010 while the advanced oil recovery technologies are being demonstrated.

In general, the types of impacts associated with widespread commercialization of these technologies were found to be similar to existing impacts. However, some chemicals used and wastes generated by technologies such as chemical flood and biotechnology differ from those of conventional technologies. Regulatory

experience developed for existing oil-recovery operations can most likely be used to mitigate potential impacts below the level of concern. Advanced oil recovery technologies with large water requirements may be constrained in areas of water scarcity or by competition with other large water users (e.g., western and central Texas, the Rocky Mountain region, and southern California). Wetlands could be sensitive to implementation of technologies that require toxic chemicals and large quantities of water in areas where water resources are limited. In oil fields located in extensive wetlands (e.g., coastal Louisiana or Alaska permafrost), construction is likely to require mitigation of impacts. Local and regional economies are likely to benefit from the continued use of existing oil-production facilities coupled with advanced oil recovery technologies.

The PEA also evaluated a no-action alternative. Compared with the proposed action, impacts under no action generally would be less at existing oil fields with abandoned wells, in which oil production would decrease by about 40% in the year 2010 compared with current levels. However, this decrease in impacts would be offset by an increase in impacts to other geographical areas that would result from additional ocean tankers transporting imported oil. Therefore, although slight adverse effects are associated with the proposed action compared with no action, there are also beneficial effects of the proposed action such as less risk of import oil spills and less risk of environmental problems associated with improperly abandoned wells.

2.3 HAZARD MANAGEMENT AND EMERGENCY PREPAREDNESS

2.3.1 Background

During the past fiscal year, IAAS staff members carried out research and development work concerning emergency planning and preparedness for accidents involving chemical agents and other hazards such as radioactive materials. Additionally, staff members developed exercise

SAMPLE EMERGENCY BROADCAST SYSTEM MESSAGE: SHELTERING INSTRUCTIONS

The following example of an emergency warning message illustrates the general principles of preparing good messages.⁴ This message instructs the public to stay indoors for protection against a vapor cloud.

The objective of sheltering is to prepare your dwelling to provide the maximum reduction of airflow from outside to inside.

All family members and pets should go indoors immediately; if outdoors, go into the nearest sound structure. Do not use a garage, shed, barn, or other buildings that appear to have a high degree of ventilation or that are open to the outside. If indoors, you should remain inside and not go outdoors.

If your children are in school, do not go to the school. The children are protected in the school building. Children will be taken to a reception center as soon as it is safe to do so. You may meet them at the reception centers when authorities say it is safe to do so.

Close and lock all exterior doors and windows in your residence. Close storm windows if this can be done quickly. Close all garage doors in integral or attached garages as well as doors normally left open for ventilation. Close all interior doors. These actions reduce air circulation in the residence.

Turn off the central heat, air-conditioning fans, ceiling fans, kitchen hood fans, and circulating fans. Extinguish all wood or coal fires and close fireplace dampers.

If possible, stay in an interior room with no walls connected to the outside of the struc-

ture, or a room with no windows, or the room with fewest doors and windows. Listen to your tone alert radio or the Emergency Broadcast System on your television or radio. These stations are _____.

After you are in the room, relax as much as possible and listen to notifications of the appropriate time to exit the shelter. People should be as comfortable as possible. You should sit still and not move around. Activity increases the speed of breathing, which will lead to a greater exposure to any vapors that might seep into the room.

Turn on a television or radio so you can be notified when it is safe to exit the shelter. Wait for the official notification from authorities that it is safe for you to leave the shelter.

After the plume passes, exit the structure to avoid any further exposure. If the structure is not vented, additional agent that seeped into the building could be inhaled after the plume has passed. Put on long-sleeved clothing, pants, and gloves. Open all windows and doors to vent the structure.

The notification system or EBS channel will provide further instructions on what to do next. Among the possibilities are

- immediate evacuation to a reception center for screening and processing,
- self/buddy decontamination, or
- waiting for emergency personnel with special vehicles to rescue people. ♦

and training programs to enhance emergency preparedness work involving disposal of chemical weapons stockpiles.

The Chemical Stockpile Emergency Preparedness Program (CSEPP) developed out of NEPA work on the U.S. Army's CSDP (see Sect. 2.2.3). Chemical agents, among the most toxic hazardous materials in existence, are stored in large quantities. The law mandating destruction of chemical weapons, however, requires maximizing the health and safety of the public. A probabilistic risk analysis for the disposal program identified a number of credible accident scenarios that could result in fatalities. Emergency planning for an accident was judged to be inadequate in the communities surrounding storage sites. In preparation of the Draft Programmatic EIS for the CSDP, ORNL proposed that the Army mitigate accidents through an enhanced community emergency preparedness program at the eight storage sites. In 1986, the Army asked ORNL to oversee development of an Emergency Response Concept Plan for the CSDP. In 1988, Undersecretary Ambrose directed the Office of the Program Manager for Chemical Demilitarization to begin implementation of that plan due to the risk of accidents from stockpile storage. To support that effort, ORNL initiated a series of technical support studies, provided technical assistance to communities in upgrading their plans, and developed more specific concept plans. Later that year, the Army entered a Memorandum of Understanding with the Federal Emergency Management Agency (FEMA) to help create the CSEPP. CSEPP has supported a variety of research and technology transfer tasks at ORNL. Centered in Energy Division, these ORNL CSEPP efforts have been funded by both the Army and FEMA. CSEPP will continue to advance novel technology in emergency preparedness. An additional benefit of CSEPP is that it will result in improved preparedness for both other acute toxic material accidents and other hazards.

2.3.2 Chemical Stockpile Emergency Preparedness Program

During FY 1992, IAAS achievements related to CSEPP include:

- *Development of improved technologies and system design for issuing public warnings.* This work involved analysis of the performance of new tone alert radio technology in conjunction with outdoor electronic sirens.¹ The new tone alert radio technology incorporates engineering and human-factor design changes that will greatly improve its reliability and availability.
- *Improved atmospheric dispersion model.* IAAS staff members have redesigned the user interface for the Army's atmospheric dispersion code and conducted a sensitivity analysis of the code. This new interface will make the model easier to use. In addition, the sensitivity analysis helped identify some mathematical errors in the model's code.²
- *Development of new integrated models for measuring dose reduction from alternative population protection strategies.* The PADRE (Protective Action Dose Reduction Estimator) model replaced the earlier PAECE model. PADRE can be used by emergency planners to analyze conditions under which sheltering people in place would be preferable to evacuating them in the event of an accidental release of chemical agent.³ Work is continuing on further integration of the models into an advanced emergency decision planning and support system.
- *Development of a state-of-the-art emergency management information system using a client-server architecture.* This effort progressed from a nonfunctioning prototype to a functional prototype tested at two Army depots. A networked ORACLE data base and front end were then developed and tested. This system will be ready for user testing in FY 1993.
- *Preparation of a guidebook on writing emergency warning messages.*⁴ This guidebook is designed to help emergency planners write effective warning messages. It can be used both for reviewing and revising existing messages and for developing new ones. The

TRANSFERRING THE CHEMICAL STOCKPILE EMERGENCY PREPAREDNESS PROGRAM (CSEPP) EMERGENCY TECHNOLOGIES

As research on emergency preparedness and response continues and new technologies are applied by Oak Ridge National Laboratory (ORNL) staff, it is necessary to transfer information and tools to end users—the persons handling emergency planning and response in the ten affected states. ORNL is applying technology transfer principles in packaging research results and technological developments into readily accessible products. One way this is accomplished is through development of comprehensive technical training that provides accurate scientific, engineering, and operational information to specialized or nontechnical personnel. ORNL provides performance-based emphasis to training, provides objectives to attain special levels of comprehension of the subject covered, and requires that technical concepts and procedures for emergency response be well-defined. This technical training matrix extends from general awareness training, which introduces participants to basic technical concepts defined in nontechnical language and fact sheets on the “whys” and “hows” of technical issues, to specialized materials designed to detail a specific job; highly technical materials on models, analyses, and operations plans; and hands-on training in automation and procedures (see Fig. 2.8).

The anticipated emergency situation is high consequence but low probability; it is not expected to occur, but if it does there could be a high likelihood

of serious health effects or even fatalities. Most trained-for emergency situations have a higher probability of occurring than do CSEPP emer-

Fig. 2.8. Complex medical information and storage site configurations were taught to emergency responders using visual techniques to demonstrate chemical agent effects from potential releases.

gencies; for example, hurricanes, tornadoes, and hazardous-material accidents occur frequently. A successful implementation strategy, adequate job aids, and training materials had to accommodate the need for performance-based materials on a variety of infrequent tasks with sufficient flexibility to be implemented within many different organizations. Modules have been developed to provide the basic knowledge-based components adapted specifically to certain job families—such as pre-hospital emergency response per-

sonnel, emergency response planners, and emergency response decision makers—to enhance performance of specific duties. As standards, guidelines, and procedures are established regarding equipment to be used, special skills required, and recommended actions, modules can be completed covering skills training and performance testing. A variety of formats is provided so that information can be tailored to its intended audiences: self-study, classroom, exercise, job aids, videos, and computer-based instruction. ♦

guidebook also provides sample messages (see highlight, "Sample Emergency Broadcast System Message: Sheltering Instructions").

- *Continued development of CSEPP's planning guidance document, standards, and supporting documents.* ORNL has prepared four volumes of such documents in support of CSEPP, including a general planning guide, an exercise handbook, a training plan, and guidelines for an automated system. Specific standards have been prepared on command and control, emergency operation centers, communication systems, alert/notification systems, traffic and access control, public education programs, and mass care. Other standards are currently under development. Together these documents define a state-of-the-art emergency preparedness program.
- *Development of Act Fast and Chemical Awareness training courses for emergency responders and other personnel in CSEPP.* Each course package consists of student and instructor's manuals, computer-based training software modules, and a set of slides (see highlight, "Transferring the CSEPP Emergency Technologies").
- *Development of an exercise program for CSEPP locations.* ORNL assisted the U.S. Army Nuclear and Chemical Agency

and FEMA in developing an exercise program for the areas around the eight Army chemical stockpile locations. These CSEPP exercises, involving both the installation and surrounding communities, are designed to test, evaluate, and improve the preparedness for an accident involving chemical munitions. This exercise program was described in three volumes, issued early in 1992: (1) a program plan, (2) standard exercise objectives and evaluation materials, and (3) guidance for conducting CSEPP exercises. These materials served as the basis for all exercises during 1992. ORNL staff observed the implementation of the exercise programs at Pueblo Army Depot Activity and Lexington-Blue Grass Army Depot and attended an exercise at Tooele Army Depot. During FY 1993, IAAS staff members will be revising the exercise materials and incorporating lessons learned.

2.3.3 Other Exercise Planning Activities

In addition to the CSEPP exercise program, IAAS staff members applied their experience in planning and conducting emergency-response exercises to work for NRC and DOE. The third Federal Field Exercise (FFE-3), a large, inter-agency field exercise of the Federal Radiological Emergency Response Plan, was scheduled for February 1993. ORNL provided planning assis-

tance to DOE headquarters by participating in the exercise-planning committees. NRC also asked ORNL to assist in developing the preliminary tabletop session and orientation workshop for FFE-3 participants. This tabletop material was completed and sent to the federal agencies in September to use for training. In October, however, the FFE-3 and tabletop session were canceled. The developed tabletop material will now be adapted for use in an NRC training program for state and local authorities.

IAAS staff members also served as technical reviewers for an exercise-planning workshop developed by the Oak Ridge Institute for Science and Education. This workshop will help exercise planners at DOE facilities develop the required full-participation exercises and accompanying documentation for DOE headquarters.

2.4 APPLIED PHYSICAL SCIENCES

IAAS continued to support safety analysis activities in FY 1992, performing flood-hazard assessments for the Paducah and Portsmouth gaseous diffusion plants (GDPs). IAAS staff members also characterized a groundwater contaminant plume in Waste Area Grouping I at ORNL (see highlight, "Migration of a Groundwater Contaminant Plume by Stratabound Flow"). Results from this study will be used to determine further remediation activities and additional investigations at the site. Also completed this fiscal year was the successful implementation of a tomographic imaging procedure for use with ground-penetrating radar technology (see highlight, "Geophysical Diffraction Tomography Aids Archaeological Research in Israel").

2.4.1 Contributions to Safety Analysis Reports

In FY 1992, IAAS hydrologists participated in regional and local flood prediction for the Portsmouth and Paducah GDPs. This work contributes to the upgrading of safety analysis reports to meet current design and evaluation criteria provided by General Design Criteria, DOE Order 6430.1A, and guidelines recommended in *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards* (referred to as UCRL-15910).

The GDPs are considered to be moderate hazard facilities because of an on-site inventory of radioactive

materials. A performance goal annual exceedance probability of 0.0001 (or a recurrence interval of 10,000 years) is applicable to this type of facility. The GDPs must meet the performance goal for regional and local floods without jeopardizing occupant safety, causing hazardous material releases, or interrupting operations.

The regional flood-hazard assessment performed along the Ohio River near the Paducah GDP used deterministic, probable maximum flood (PMF) methodology. Probabilistic flood-prediction methodology was implemented to estimate Scioto River surface elevations adjacent to the Portsmouth GDP. The Paducah GDP is located along the lower main stem of the Ohio River, where extreme floods occur during a storm sequence rather than during a single storm. Insufficient meteorological data are available to calculate the joint probabilities of a storm sequence. As a result, PMF methods were selected to assess the extreme regional flooding potential at the Paducah GDP. The PMF has a long, unknown recurrence interval that usually exceeds 10,000 years. Probabilistic flood models used for the Portsmouth GDP assessment included Gumbel's extreme value theory, the log Pearson III probability distribution, and linear least-squares methodology.

An additional benefit of CSEPP is that it will result in improved preparedness for both other acute toxic material accidents and other hazards.

Figures 2.9 and 2.10 show results from the GDP extreme-flood studies. The Paducah GDP is located upstream from Cairo, Illinois, while the Portsmouth GDP is located downstream from the U.S. Geological Survey gaging station near Higby, Ohio. The HEC-2 computer program for gradually varied, open channel flow was used to calculate Ohio River surface elevations adjacent to the Paducah GDP, using measurements recorded at Cairo as an initial condition.

Fig. 2.9. Ohio River flood elevations.

The upper branches of the curves shown in Fig. 2.9 do not account for changes in hydraulic geometry that would occur during extreme floods, while the lower branches include effects attributable to overbanking that lower predicted PMF levels.

The probabilistic flood level predictions presented in Fig. 2.10 near the Portsmouth GDP exhibit explicit recurrence interval variation. Recurrence intervals for the measured Higby flood flows, which appear as open circles in Fig. 2.10, were calculated using a Weibull analysis. The three probabilistic models were then used to extend measurements to 10,000 years. The PMF level for the drainage area above Higby is in relatively good agreement with results obtained from the probabilistic models. In Fig. 2.10, the PMF elevation plots as a horizontal line because of its relatively long, unknown recurrence interval. Results from the two studies represented in Figs. 2.9 and 2.10

demonstrate that the main process buildings at both GDPs would not be inundated during extreme regional floods, and that DOE Order 6430.1A and UCRL-15910 recommendations were satisfied.

Figure 2.11 displays simultaneously the results from both the PMF and probabilistic regional flood studies. The area of the Ohio River drainage basin exceeds the size of the Scioto River basin by two orders of magnitude. A comparison of the results from these two assessments indicated that the PMF recurrence interval exceeded the 10,000-year requirement of the guidelines, while recurrence intervals obtained in the Portsmouth assessment could be above or below 10,000 years, depending on the choice of the probabilistic flood model. These results further suggested that smaller watersheds driven by single-event storms could be assessed using probabilistic techniques, while PMF methodology could be applied to larger drainage basins flooded by storm sequences.

The local flood-hazard assessments for the GDPs evaluate the potential for inundation of the main process buildings from creeks, ditches, storm sewers, culverts, and roof drainage systems during an extreme storm with an approximate recurrence interval of 10,000 years. Pondered rainwater on roofs was analyzed with primary drainage systems clogged (as recommended in UCRL-15910), while creeks, ditches, storm sew-

Fig. 2.10. Scioto River flood elevations.

Fig. 2.11. Watershed size vs recurrence interval (not to scale).

ers, and culverts were assumed to be open and totally available for the flow of storm water.

Rainfall intensity-duration-frequency curves were used to construct the extreme storm and were then combined with runoff models to obtain storm flows. Figure 2.12 graphically illustrates the extrapolation procedure deployed to obtain the Paducah GDP 10,000-year precipitation vs storm-duration relationship from measurements. A methodology was developed to predict the maximum average depth of ponded rainwater on urbanized surfaces drained by storm sewer systems during extreme storms. Standard methods from hydraulics and hydrology were used to predict local storm water levels based on the quantity and flow rate of undrained rainwater.

Results from the local drainage analyses indicated that local flooding from creeks and ditches would not threaten the main process buildings at the GDPs. However, results also reveal that the storm sewer systems, culverts conveying ditch flows beneath roadways and railroads, and roof drainage systems have insufficient capacities to accommodate extreme storm flows. Problem areas were identified for further study. Mitigative measures were suggested to ensure that the integrity of the main process buildings, as well as other critical, safety-related facilities, would not be jeopardized during locally intense, extreme precipitation events.

2.4.2 Geophysical Tomography

For the past 8 years, ORNL has been developing techniques for shallow subsurface imag-

ing based on the principles of geophysical diffraction tomography (GDT). GDT is an imaging procedure in which the signal received from a wave source that has propagated through a subsurface region is back-propagated into this region to map spatial variations in subsurface properties. This method is an application of the well-known straight-ray imaging algorithms employed in computerized tomography scanners for nondestructive evaluation and diagnostic medicine, generalized to the longer wavelengths that must be used when

imaging in geologic material. Conceptually, GDT is quite similar to the imaging procedure underlying optical holography.

The earliest work in GDT was directed toward imaging shallow buried wastes using acoustic waves. To field test the imaging procedure, researchers built a specially designed data acquisition system. With this system and acoustic waves, GDT was used to image a number of buried waste forms, soil strata, and the buried skeletal remains of *seismosaurus*, the longest dinosaur ever discovered.

Another recent development in GDT is the successful implementation and field testing of a tomographic imaging procedure for use with ground-penetrating radar (GPR) measurements. GPR most commonly uses a pair of microwave

Fig. 2.12. Precipitation vs recurrence interval at the Paducah Gaseous Diffusion Plant for specified storm durations.

MIGRATION OF A GROUNDWATER CONTAMINANT PLUME BY STRATABOUND FLOW IN WASTE AREA GROUPING 1 AT OAK RIDGE NATIONAL LABORATORY

Geologic and hydrologic methods were employed this fiscal year to identify the three-dimensional nature of a groundwater contaminant plume in Waste Area Grouping (WAG) 1 from a single point datum. One element in an overall conceptual model for groundwater flow in WAG 1 is described that apparently controls and can predict plume migration from a source area near core hole CH-8 located south of the Oak Ridge National Laboratory (ORNL) cafeteria (Building 2010) to the plume discharge area near First Creek (Fig. 2.13). Using a working hypothesis of stratabound groundwater flow and contami-

nant transport, investigators analyzed existing subsurface geologic data to predict the contaminant plume discharge location in First Creek, as well as locations of contaminated groundwater seepage into storm drains. The hypothesis states that the differential lithologic/fracture conditions lead to the development of preferred flow and transport pathways of discrete vertical extent, which may not necessarily follow the hydraulic gradient. Leakage out of the stratabound pathway is a minor component of the overall plume configuration.

Fig. 2.13. Gross beta contamination in contaminant plume, sampled storm drains, and storm drain outfalls.

Results of this analysis indicate that application of the stratabound pathway hypothesis accurately predicts the plume discharge location in First Creek, which is 65° oblique to the general gradient in that portion of WAG 1. Plume identification subsequently provided an explanation for historical contamination in WAG 1 piezometers and water-quality wells that was not previously understood. Analysis of the subsurface storm drain in the vicinity of the plume also explained the historical contamination in storm drain outfalls of First Creek and verified the comparatively minor role of upward leakage from the stratabound

pathway to the water table, as described by the hypothesis.

Characterization of the groundwater contaminant plume in the western portion of WAG 1 will be used to determine remediation alternatives and additional investigations to more fully describe both the three-dimensional character of the plume and its source location. The development of a highly accurate, predictive capability in groundwater contaminant migration at ORNL, demonstrated by the results of this study, will be applied to ongoing numerical groundwater analyses at ORNL and other WAGs on the Oak Ridge Reservation. ♦

ORNL-Photo 1063-93

Another recent development in GDT is the successful implementation and field testing of a tomographic imaging procedure for use with ground-penetrating radar (GPR) measurements. GPR most commonly uses a pair of microwave antennas towed in unison along the ground surface. GPR can also be used to survey large spatial extents in a relatively short time, making it a practical and common geophysical tool for shallow applications.

Alan Witten performs research on Geophysical Diffraction Tomography techniques for subsurface imaging.

GEOPHYSICAL DIFFRACTION TOMOGRAPHY AIDS ARCHAEOLOGICAL RESEARCH IN ISRAEL

This past year has seen many new developments in geophysical diffraction tomography (GDT). A new acoustic-based data acquisition system was developed and successfully field tested. This system is rugged, quite portable (it can be transported as carry-on luggage), and capable of generating images in near-real-time in the field. Two such systems were built. The first has been delivered to the U.S. Environmental Protection Agency for use at Superfund sites. The second system remains at Oak Ridge National Laboratory. In June, this system was taken to Israel at the request of the Israeli Minister of Science and Technology to conduct imaging studies

at archaeological sites. The most interesting of these sites is Shiqmim, located in the Northern Negev desert, where archaeologists recently discovered a subterranean complex of chambers and connecting tunnels inhabited by a prehistoric civilization approximately 6500 years ago (Fig. 2.14). Originally excavated in hard-packed soil, the features are difficult to locate and identify because they have been completely filled in with soft soil as a result of erosional forces for more than six millennia since their abandonment. The primary purpose of GDT field studies at this site was to demonstrate that these features of interest could be imaged and subsequently

ORNL-Photo 7290-92

Fig. 2.14. One room in a previously discovered complex and a tunnel, at right, leading to another room.

to evaluate whether this subterranean habitat extended beyond the system originally discovered.

GDT could in fact resolve these features; this subterranean civilization was more extensive than anticipated. Figure 2.15 is an image of a vertical subsurface cross section displaying newly discovered underground features. The imaged quantity here is the so-called "object function," which is related to the acoustic refractive index that, in turn, is a composite function of mechanical properties. At Shiqmim, variations in object function are dominated by differences in densities. The sediment-filled rooms and tunnels are characterized by a density slightly lower than that of the surrounding hard-packed soil. In Fig. 2.15, spatial variations in object function are displayed as gray levels, with darker

shades of gray signifying greater densities. The contrast of this image has been increased to accentuate the rooms and tunnels, which appear as white features. A room is evident in this image as the 7-m-deep white area centered at 4 m from the reference borehole containing the receiver array. A steep diagonal tunnel appears to be extending from the top of this room toward the ground surface. This is likely one point of access for this particular room system. A second white feature at a depth of 3.5 m and 10 m from the borehole is a tunnel oriented perpendicular to the plane of the imaged cross section. Similar images obtained in this general area reveal a three-dimensional "picture" of a portion of a new room and tunnel sequence with at least five interconnected rooms. ♦

Fig. 2.15. Example of a geophysical diffraction tomography image at a prehistoric archaeological site in the Negev desert, Israel. Shown in this image is a vertical cross-section through a portion of an underground sequence of rooms and connecting tunnels.

2.5 TECHNOLOGY AND SOCIAL SYSTEMS

IAAS's research activities in technology and social systems focus on three main areas: (1) social impact analysis; (2) energy-efficiency program evaluation; and (3) societal responses to technology. Highlights of FY 1992 projects in each of these areas are described in the following sections and in highlight, "IAAS Staff Member Serves as Senior Editor of the *Forum for Applied Research and Public Policy*."

2.5.1 Social Impact Analysis

IAAS staff members continued to provide social and cultural impact analysis for various NEPA documents prepared by the Energy Division. The group's effort focused on projects requiring innovative methodologies and creative analysis, as well as allowing for significant contributions to the body of knowledge on social and cultural impact assessment. For example, two FERC projects, the *Environmental Impact Statement for Nine Proposed Hydroelectric Projects in the Skagit River Basin, Washington* and the *Environmental Impact Statement for Seven Proposed Hydroelectric Projects in the Nooksack River Basin, Washington*, have presented a number of issues related to recreational, visual, and Native American cultural resources, requiring innovative analysis and assessment techniques.

The staff's assessment indicates that the adverse environmental impacts of small hydropower development in the Skagit and Nooksack basins would be less severe than those of timber harvesting and road construction. The assessment also reveals that, generally, the projects' impacts to recreational, visual, and cultural resources would be relatively minor and limited to the stream basins in which individual projects would be constructed. For those projects where site-specific impacts would be significant, or where minor effects would contribute significantly to cumulative impacts for the entire river basin, mitigation measures were developed. The process of developing appropriate mitigation measures has been especially challenging, re-

quiring staff members to associate both monetary and nonmonetary values with the recreational, visual, and cultural resources that make these river basins unique.

2.5.2 Energy-Efficiency Program Evaluation

Several evaluation efforts this year were concerned primarily with integrated resource planning (IRP) by electric utilities. A new interactive approach to reaching agreement among utilities and non-utility parties (NUPs) on demand-side management (DSM) program design and policy issues, called the collaborative process, was studied extensively for DOE's Office of Conservation and Renewable Energy. Nine cases of DSM collaboration were examined, involving 24 utilities and approximately 50 NUPs in 10 states. This was the first comprehensive, in-depth review and assessment of collaboratives allowing conclusions to be drawn about the collaborative process and the factors that contribute to successful efforts of this type (*Public Involvement in Integrated Resource Planning: A Study of Demand-Side Management Collaboratives*⁵). Data were collected through a review of primary and secondary sources for each case and through personal interviews (at three sites) and extended telephone interviews (at the remaining six sites). After these data were collected and tabulated, staff members performed a qualitative analysis to identify contextual and organizational characteristics related to collaborative success.

Key findings include the following observations: (1) a high degree of consensus was observed across the collaboratives, although parties resolved technical issues more easily than they reached agreement on DSM policy issues; (2) collaboratives worked well in satisfying participants' objectives (in nearly all cases, multiple parties reported high overall satisfaction of their objectives); (3) DSM collaboratives are resource-intensive but promise to save time and money in the long term and lead to outcomes qualitatively superior to the expected results of litigation; (4) most of the collaboratives were initiated in the aftermath of extensive intervention on DSM issues by NUPs from public and private

sectors, but a utility's decision to collaborate will also strongly reflect its own strategic objectives (e.g., the settlement of a power plant siting dispute); (5) the historic interest shown by utility regulators in promoting aggressive DSM programs by utilities can be an important stimulus for the formation of DSM collaboratives and may be a necessary precondition; and (6) properly structured collaboratives can be effective for addressing a wide range of DSM-related issues, but the process works best only where convergence on important issues by most parties seems possible.

An ongoing follow-up study focuses on the initiation and operation of ten interactive efforts related to IRP and DSM issues. Nearly all of the cases examined in the new study are different from those examined previously, and the new study moves beyond the former emphasis on east and west coast collaboratives (the earliest efforts of this kind) to include four cases in southern states, one in the industrial midwest, and one in the mountain west. This 2-year study, which employs the same data collection and analysis techniques described for the earlier collaboratives study, is expected to yield more information on the ways in which collaboratives and other interactive efforts are initiated and on the factors that influence the process design to develop DSM programs.

A related study completed in FY 1992 examined the DSM program development process of 13 electric utilities. Data were collected through lengthy telephone interviews with utility personnel, through personal interviews conducted during site visits to three utilities, and through a review of utility documents and published literature. This study (*The Demand-Side Management Program Development Process—A Utility Perspective*⁶) allows outsiders a detailed look at the DSM planning process and provides insight into the factors that motivate and affect DSM programs from the utility's perspective; it also provides utility planners information against which to compare their own beliefs, perceptions, and motivations concerning DSM planning.

Key findings include the following: (1) utilities can be categorized according to their technology orientation or customer orientation (technology-oriented utilities generally ap-

proach DSM from an engineering perspective, while customer-oriented utilities emphasize the importance of customer needs and satisfaction); (2) DSM planning can be characterized as iterative, interactive, flexible, adaptive, and variable (both over time and at any given time, depending on the program developers and market being served); and (3) utilities new to DSM must make a number of key decisions about the planning process, including what the functional responsibilities of the demand-side planning group should be, what role outside consultants will play in program design and plan development, where the demand-side planning group should be located in the organization's reporting structure, and whether to offer a few comprehensive programs or many specific programs.

2.5.3 Societal Responses to Technology

Research on social, cultural, political, and historical aspects of public responses to controversial technologies has complemented IAAS research in social impact analysis. Societal responses to technologies may range from absolute rejection to enthusiastic acceptance. The primary emphasis of the analysis has been on the characteristics of communities (e.g., socioeconomic status, education level, and industrial development), technologies (e.g., their maturity, past precedents regarding occupational and public safety, and their typical management and oversight), forces external to communities (e.g., the regional or national need to site a particular facility, and the extent of outside control over decision making), and the nature of decision making (e.g., the kind, extent, and timing of local public involvement). This year, along with members of the Energy and Economic Analysis Section, IAAS staff members investigated social and economic influences on decisions to site municipal waste-to-energy (WTE) facilities at four U.S. sites. Section 3.3.1 presents an overview of the project, emphasizing its economic and financial elements.

This case-study analysis distinguished between the decision-making process and decision outcomes, recognizing that all aspects of the process clearly are linked to outcome. Case-study findings indicate that similar decision-

IAAS STAFF MEMBER SERVES AS SENIOR EDITOR OF THE *FORUM FOR APPLIED RESEARCH AND PUBLIC POLICY*

A quarterly publication on policy issues in energy, environment, science and technology, and economic development, the *Forum for Applied Research and Public Policy* (*Forum*) was begun at the Tennessee Valley Authority in 1986. In 1988, management of the journal was moved to the Energy, Environment, and Resources Center (EERC) at the University of Tennessee, which continues to house the periodical's editorial and production staff. In late 1990, the *Forum* became a joint undertaking of EERC and Oak Ridge National Laboratory (ORNL). Over the past year, the *Forum* has won two awards for editorial excellence from the International Association of Business Communicators and the International Society for Technical Communication.

D. L. Feldman, a staff member of the Hazard Management Group in the Integrated Analysis and Assessment Section, began serving as one of two senior editors of the *Forum* in December 1990. This position has three responsibilities: (1) symposia development and manuscript acquisition, (2) author and reviewer contact and liaison, and (3) acquisition of new titles for review in the *Forum* book-review section. The editors' primary responsibility is to identify topics that can be explored in future issues of the journal, which

requires a vision of what would make an interesting, informative series of articles on a topic. It entails a blending of various elements ranging from representation of diverse points of view to author affiliation, geographic balance, and even academic vs practitioner viewpoint. What makes the *Forum's* voice unique is that articles are featured in "symposia"—sections of four to six interrelated articles. Each symposium contains a peer-reviewed lead article and a series of follow-up articles that provide various perspectives on the topic.

Feldman has taken the lead in developing symposia on the National Environmental Policy Act, the impact of the National Acid Precipitation Assessment Program, the future of the U.S. space policy, energy issues in developing countries, demand-side management, a special waste management issue, western water resources, food policy, the future of Antarctica, alternative motor vehicle fuels, environmental education, chemical weapons negotiations, and marine environmental issues. These topics will appear in 1993–1994 issues of the *Forum* and will involve the participation of internationally recognized scholars, policy makers, and business leaders, including many researchers from ORNL. ♦

making processes need not lead to similar outcomes. Additional findings include the following: (1) perceptions of the immediacy of the need for waste management capacity influenced decisions; (2) the timing of project initiation and implementation, as well as national-level changes, affected the decision-making process; (3) ownership selection and vendor options were not strong factors affecting decisions; (4) the size of the proposed facility relative to the size of the waste stream was a significant decision-making factor; and (5) no clear link existed between siting activities or site characteristics and the outcome of WTE decision making. Finally, while no single contextual factor may have been significant enough to affect the WTE decision, the occurrence of a sequence of factors, in concert, did differentiate sites where WTE was accepted from those where it was rejected.

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E n e r g y a n d
E c o n o m i c
A n a l y s i s
S e c t i o n

*C. R. Kerley
Section Head*

3

ENERGY AND ECONOMIC ANALYSIS SECTION OVERVIEW

3.1 INTRODUCTION

The Energy and Economic Analysis Section (EEAS) specializes in economics research. The section is staffed with economists trained in such areas as energy economics, natural resource and environmental economics, public policy studies, applied microeconomic theory, econometrics and mathematical modeling, and economic geography and regional science. Most of the professional staff members hold doctoral degrees. EEAS maintains an independent research agenda for the U.S. Department of Energy (DOE) and other sponsoring agencies and supports research projects in other Energy Division sections and other Oak Ridge National Laboratory (ORNL) divisions. Collaborative research with university programs is accomplished through joint research staff appointments to EEAS and a university.

During fiscal year (FY) 1992, two collaborating scientists—Milton Russell, former Assistant Administrator for Policy and Planning at the U.S. Environmental Protection Agency (EPA) and University of Tennessee- (UT-) ORNL appointee, and James Kahn, UT-ORNL Associate Professor and research staff member—have cooperated with EEAS staff on various research initiatives. Russell continued two important initiatives: (1) a study of energy and environmental policy in China, and (2) the National Acid Precipitation Assessment Program, in which he participates on the Oversight Review Committee.

3.2 INFORMATION TRANSFER

An important objective of the EEAS research program is to disseminate research information to DOE, other government agencies, the scientific community, the public, and appropriate agencies within developing countries. Staff

members publish the results of EEAS research in refereed journals and make frequent presentations to scientific conferences and workshops, national advisory boards, and Congress. This year, two staff members participated in off-site assignments with the Office of Technology Assessment (OTA) and DOE's Secretary of Energy Advisory Board (SEAB). Anthony Turhollow participated on an OTA team that prepared a book on biomass energy. David Bjornstad continued his special assignment with SEAB to set forth a plan for expanding and institutionalizing economic policy analysis in DOE.

Milton Russell was selected to head a new research and training center titled the Joint Institute of Energy and Environment. The center is cosponsored by DOE-ORNL, UT, and the Tennessee Valley Authority. The institute's multiple objectives will combine the applied research strengths of the three sponsoring agencies and facilitate the participation of nongovernment partners such as the Rockefeller Foundation. Russell will oversee efforts to transfer research and technical knowledge more effectively to solve energy needs in developing countries and to train domestic and foreign public officials in environmental awareness, regulatory compliance, pollution prevention, and environmental management. The institute will continue EEAS's pathfinding investigation in China, including Hainan, Yunan, and the upper Mekong River provinces. These efforts involve creating specialized economic zones, conducting research in biomass gasification, and using integrated resource planning (IRP) and demand-side management (DSM) as energy resource substitutes for expanded coal use in China.

3.3 RESEARCH PROGRAM

EEAS research projects consist of three broad categories: (1) productivity and energy supply, (2) energy and environment, and (3) modeling and technology. These research activities are conducted by two groups in the section—the Energy and Environmental Economics Group, led by David J. Bjornstad, and the Resource Modeling and Technology Economics Group, led by Russell Lee. The sample

of these two groups' research efforts discussed in the following sections demonstrates how other government agencies benefit from DOE research and how interdisciplinary teams from ORNL divisions, universities, and private research organizations are advancing scientific understanding of world energy and environmental issues.

3.3.1 Productivity and Energy Supply

The projects concerning productivity and energy supply research assist DOE and other agencies in addressing policy issues related to strategic fuel reserves, energy security, energy efficiency, and energy technology options. Investigations in energy technology options this year have focused on employing biomass energy technology in China and examining causes of the waning interest in municipal solid waste (MSW) combustion in the United States.

A biomass-to-electricity project in Yunnan Province, China, is awaiting formal approval following financial and economic analysis conducted in December 1992 with assistance from a team led by Milton Russell. This decision builds upon work initiated in 1989 and supported by ORNL staff over the last 2 years. Three candidate installations were analyzed: (1) conversion of the Dongfeng sugar mill in Baohan City, 6 MW

ORNL-Photo 1601-93

A team including Bob Perlack, Milton Russell, and Larry Hill (from left) conducted financial and economic analysis of energy issues in China.

electric; (2) conversion of the Qina sugar mill in Yongsheng County, 5 MW electric; and (3) construction of a new stand-alone generic 12-MW electric power plant. The Chinese decided to authorize and fund development of the Yongsheng facility, and in anticipation they had planted trees adequate to supply wood for more than the first 2 years.

The underlying factors involved in the analysis of each prospective facility are different but turned out to be somewhat offsetting. The estimated internal rate of return for each facility is about 15%. A sensitivity analysis was conducted that degraded each of the key inputs by 25% (or a similar factor), and in no case did this drive the results significantly downward. In each of the cases examined, the net present value on a 10% discounted cash flow basis was substantial and positive.

For analysis on the revenue side, the tariffs were based on a survey of what consumers were actually paying for different classes of service. This was done in recognition of the substantial unsatisfied demand even during seasonal periods when existing hydro-based supplies are at their greatest. The Chinese concluded that revenues could be made more adequate to cover any ultimate costs. On the costs side, estimates were based to the extent possible on existing wage and material rates and on published costs of purchased equipment.

No explicit quantitative economic analysis of external costs and benefits was conducted, but the qualitative analysis concluded that net externalities were both substantial and positive and that financial costs clearly exceeded economic costs (based on opportunity cost concepts), with the exception of land value, which the Chinese calculated at zero. (A sensitivity case on land cost did not show marked significance.)

Although the opportunity cost of capital is substantially higher than 15% in China, the Chinese concluded that the project could be fi-

nanced in direct revenue terms and was desirable on economic and environmental grounds. Consequently, the Chinese have expressed great interest at both the provincial and the national level in exploring the extent to which similar projects can be developed and learning ways of encouraging such development. They are also interested in pursuing research to increase forest productivity and in using more advanced conversion technology than is currently planned for next-generation facilities.

Investigations in energy technology options focused on employing biomass energy technology in China and examining causes of the waning interest in municipal solid waste combustion in the United States.

The second energy technology investigation focused on U.S. communities considering MSW projects. Commonly called waste-to-energy (WTE), this technology was adopted by many U.S. communities during the 1980s to manage their grow-

ing quantities of MSW. Although less than 1% of all U.S. MSW was burned for its heat energy in 1970, WTE grew to account for 16% of MSW in 1990, and many experts forecast that WTE would be used to manage as much as half of all garbage by the turn of the century. As these forecasts are increasingly challenged by recent WTE project cancellations, the long-run viability of WTE is in question. A total of 248 WTE projects in various planning stages were canceled between 1982 and 1990. While only 8 projects were scratched between 1982 and 1984, 207 were abandoned between 1986 and 1990. Only 147 U.S. facilities were operational in 1990, so the total number of WTE facilities abandoned between 1986 and 1990 exceeded the total number operating in 1990 (see highlight, "Viability of Waste-to-Energy Projects").

3.3.2 Energy and Environment

Energy and environment projects include the following issues in economic analysis: conventional energy use, substitution of biomass fuels in developing countries, protection and reestablishment of natural environmental sys-

VIABILITY OF WASTE-TO-ENERGY PROJECTS

Why have so many waste-to-energy (WTE) projects been canceled, and what does this say about the long-run viability of WTE in the United States? A study directed by T. R. Curlee took an in-depth look at these questions by assessing the numerous socio-economic factors, financial views, and processes that have played a role in community decisions regarding WTE as a component of solid-waste management strategies. The three-pronged approach investigated (1) the relationships between a municipality's decision to accept or reject WTE and key socio-economic parameters, (2) the potential impacts of recent changes in financial markets on the viability of WTE, and (3) the WTE decision-making process and the socio-economic parameters that most influence a municipality's decision. The first two objectives involved collection and analysis of aggregate data on all U.S. WTE initiatives from 1982 to 1990. The latter objective entailed four in-depth case studies—two directed at communities that have accepted WTE, and two that have canceled WTE projects. In Oakland

County, Michigan, and Broward County, Florida, WTE projects were approved; in Broward County, two WTE facilities are now operational. In Monmouth County, New Jersey, and Knox County, Tennessee, planned WTE facilities were canceled.

Overall, the study identified 657 WTE initiatives in 354 counties dating back to 1982—227 projects in various stages of planning, 147 operational facilities, 248 canceled projects, and 35 facilities that have been shut down. Almost two-thirds of all WTE initiatives occurred in metropolitan (metro) counties, 54% of which had populations in excess of 100,000. Nonmetro counties account for 30% of WTE initiatives. Large mass-burn technologies are used predominantly in metro areas, while modular systems are used most often in nonmetro areas.

The study concludes that nonmetro counties have scratched slightly more facilities than metro counties have—42% of all initiatives in nonmetro counties and 37% in metro counties. Counties with WTE initiatives are generally wealthier, more educated (i.e.,

a higher percentage of residents completing high school), less blue collar (i.e., a lower percentage of workers in manufacturing, mining, and construction), and less rural (i.e., a lower percentage of population in a rural environment) and have a higher percentage of individuals in what is called the "builder" stage (22 to 39 years old).

In the financial review, data showed that the costs of WTE facilities have increased sharply. When adjusted for inflation, the capital costs of existing and planned facilities increased from an average \$43.8 million in 1982 to \$52.4 million in 1990 (in 1982 dollars). More revealing, the mean adjusted cost of

ORNL-Photo 1449-83

Dave Vogt, Susan Schexnayder, Dave Feldman, Randy Curlee, and Amy Wolfe (from left) study the viability of waste-to-energy projects.

planned facilities increased by 40.6% between 1982 and 1990, from \$62.1 million to \$87.3 million. During this same time frame, the federal government imposed new restrictions on the types of local debt that could qualify for federal tax-exempt status and placed unified volume caps on each state's allotment of tax-exempt, private-activity bonds. The study concludes that innovative financial instruments are increasingly available to help overcome the financial obstacles imposed during the 1980s.

Once a WTE project has been initiated, the decision to proceed with or abandon that project appears to depend largely on the dynamics of the decision-making process and the interactions of concerned parties. Future research is needed to build upon these previous case studies to identify methods to assist communities in their decisions about waste incinerators. Leaders acknowledge this topic to be one of today's most divisive and complex waste issues. ♦

tems, interaction between agriculture and the environment, and air quality concerns.

A major initiative managed by EEAS staff this year is the DOE Fuel Cycle Project, a multiyear study that is examining the true cost to society of inadvertent and unaccounted-for externalities (effects of fuel use on the welfare of people). The classic example of unregulated pollution from a smokestack serves to illustrate these externalities. Here, a factory produces products that are priced by taking into account the demand for the products and labor, land, material, capital, and other costs; however, the damages (and benefits) from the factory's emissions—health and other effects—are true costs to society that are unaccounted for in the product prices. The United States has increasingly recognized that the lack of high-quality information on externalities is distorting decision making both at the federal level, in terms of allocating energy research and development budgets, and at the state public utility board level, in terms of conservation and technology choice.

In February 1991, DOE and the Commission of the European Communities (CEC) signed a joint statement regarding the external costs of fuel cycles. This 18-month agreement committed their respective organizations to "develop a comparative analytical methodology and to develop the best range of estimates of external costs from existing data and completed research" for eight fuel cycles and four conservation options. In this study, a fuel cycle is defined as the series of physical and chemical processes and activities

required to generate electricity from a specific fuel or resource.

Lead responsibilities for the fuel cycles were distributed between the two research teams as follows: both teams will undertake the coal fuel cycle and conservation options; the United States will lead on biomass, oil, natural gas, and small hydroelectric energy cycles; and the CEC will lead on uranium, photovoltaic energy, and wind cycles. The Federal Energy Regulatory Commission (FERC) is also a participating cosponsor in the U.S. study. The U.S. study team was created by bringing together research staff at ORNL and at Resources for the Future. A similar study team was organized for the CEC effort. As defined by the teams, primary objectives of the study are

ORNL-Photo 1058-93

Russ Lee heads the fuel cycle study.

1. to create a unified conceptual design for quantifying the various costs and benefits associated with the production and consumption of energy from different fuel sources;

2. to demonstrate an accounting framework for estimating the static measures of a broad range of costs (and benefits) that result from incremental use of different fuel types, and to use this information in a comparative analysis of fuel types; and

3. to identify critical methodological issues and information needs that will affect the expanded efforts to later develop comprehensive assessments of energy-use costs.

The foundation phase of the study is limited primarily to developing and demonstrating methods for estimating impacts and their monetized value, termed "damages" or "benefits," leaving aside the extent to which such damages have been internalized. Also, instead of fully examining all "secondary source" fuel-cycle damages, benefits, and private costs, this study concentrates mainly on the incremental or marginal nonmarket damages and benefits from additions to electrical generation capacity. The study also limits consideration of certain fuel-cycle stages. A total energy cycle includes (1) primary resource extraction and preparation, (2) transport and storage of resources and materials, (3) processing and conversion to electricity (i.e., generation), (4) end-use services, and (5) disposal. Except for the conservation options, this fuel cycle study concentrates on the first three stages and on disposal.

Figures 3.1–3.3 illustrate the complexity of the fuel cycle process, highlighting a few of the many impact dimensions associated with the coal fuel cycle. The principal types of surface coal mining in mountainous terrain are contour mining and mountaintop removal, and in non-mountainous areas, strip

mining. In general, the topography is altered, former land uses (forest, crops, pasture, and rangeland) are displaced until the mines are reclaimed, and soil productivity is adversely affected for as long as 30 years.

As shown in Fig. 3.2, coal cleaning, with its attendant generation of refuse, is done primarily where high-sulfur coal is mined in the central interior and eastern areas of the United States. The primary impact on terrestrial resources is the displacement of land by refuse disposal areas (gob piles and slurry lagoons). Terrestrial environments near such disposal areas can be impacted by wind-blown coal fines and acid drainage from the refuse.

Potential sources of transportation impacts on terrestrial resources include:

- land requirements and disruption for new railroad spurs and haul roads to mine sites,
- land requirements and disruption for new loading and unloading facilities for barges, and
- accidental spillage and wind-blown coal dust associated with mobile coal cars and trucks.

Fig. 3.1. Direct impacts from mining and cleaning of coal.

Fig. 3.2. Beneficiation and transportation of coal.

As shown in Fig. 3.3, the generation stage (stage 3) will impact terrestrial resources by replacing land with generating facilities and releasing gaseous emissions. Gaseous and particulate emissions can decrease visibility over vast areas. Aesthetic quality at parks in the southeastern and southwestern United States has been adversely affected by pollution-caused decreases in visibility, although natural haze and automobile exhaust are also major contributors. The greatest impact from new power lines occurs when forest must be cleared to accommodate new corridors. In general, a large number of other physical and socioeconomic impacts are associated with these effects as well.

Because of the diversity of potential fuel-cycle exter-

nalities, a number of analytical tools are being developed to implement the study approach. These tools are necessary to *name* impacts, *quantify* what has been named, *translate* physical quantities to damages, and finally *distinguish* damages from external costs. These steps produce the damage function approach (DFA). The DFA attempts to combine natural science and economics to reveal as many changed relationships as possible from the incremental investment. For incremental damage or benefit estimates, the DFA begins with residual emissions from each fuel-cycle activity necessary to support the incremental investment and

Fig. 3.3. Electricity production from coal.

changed concentrations of pollutants that are spatially and temporally distributed; (2) the physical response of ecological, human, and social resources (also spatially and temporally distributed) to changed concentrations; and (3) how these responses are valued by the individuals affected.

Figure 3.4 is a flowchart that captures the DFA process and accurately reflects how the fuel cycle study approach is organized. Each stage of each fuel cycle implies a limited number of technical options given the scenario assumptions. Once abatement technology and locational conditions are considered, the approach lists or names particular activities and their residual emissions. To the extent these emissions can be separated into meaningful pollutant species and their rates quantified, the next step is to use transport modeling (via air or water) and the physical characteristics of the site to quantify changed concentrations, doses, and resource responses. These responses then define the set

of physical impacts. Next, monetary values are assigned to the physical or social impacts. The last step of the analysis, which is not emphasized in this first phase of the project, will consider the distinction between damages and external costs by referencing, for instance, existing regulatory and civil law arrangements that may act to internalize externalities. Preliminary results from applying this DFA process should be available later in FY 1993.

In a second energy and environmental project, EEAS staff members participated on a draft environmental impact statement (DEIS) prepared for FERC that considers modifications to the Lower Mokelumne River Project. The project is a multipurpose, multireservoir system licensed in 1981 to the East Bay Municipal Utilities District (EBMUD) of Oakland, California. Chinook Salmon and Steelhead Trout in the lower Mokelumne River have experienced recent population declines and fish kills associated partly with discharges from Camanche Dam.

Other stresses, such as irrigation diversions and acid mine drainage, have been affecting fishery resources in the lower river for most of the 1900s. As defined more completely in Sect. 2.2.1, a wide range of potential mitigatory actions were identified in the DEIS scoping process, and three alternatives were designed to improve conditions for naturally spawning salmon and trout in the lower river. These were plans proposed by (1) the California Department of Fish and Game (CDFG), (2) EBMUD, and (3) the DEIS staff. As shown in Fig. 3.5, economic analysis suggests that under a worst-case, 3-year drought, the CDFG minimum flows would produce a supply

Fig. 3.4. Impact-pathways of the damage function approach.

deficit of approximately 123 thousand acre-feet (TAF)/year with an annual cost of replacement to EBMUD of over \$20 million. In comparison, EBMUD's minimum flows would produce a worst-case deficit of 71 TAF/year and a replacement cost of \$11.9 million. The DEIS staff's minimum flows would produce a worst-case deficit of 95 TAF/year and a replacement cost of \$15.1 million. The DEIS staff recommended a combination of flow and nonflow modifications to the existing license, based on this analysis, and a series of studies and monitoring to determine feasible means for solving off-site fish-passage problems.

EEAS staff members Bob Perlack, Larry Hill, Milton Russell, and Zhong-min Shen (a UT student working with ORNL staff) maintained important international roles by continuing research on energy planning and environmental policy in developing countries. Much of the international research effort focuses on achieving energy efficiency, protecting the environment, and transferring new concepts such as DSM and IRP to developing countries. DSM, changing the pattern and level of electricity demand, is weighed as a resource option on equal footing with traditional supply resources such as constructing new electricity-generating plants. The IRP process is a combination of traditional least-cost planning, a process by which utilities minimize the cost of generating a given amount of electricity, and demand-side planning.

In a report related to Hainan, China's resource options,¹ EEAS staff members identified a strategy that (1) provides future energy services for Hainan in the least environmentally degrading way; (2) eliminates the need to build significant amounts of new fossil-fueled, electric-generating capacity, thereby saving capital to invest in other development projects; (3) lowers the cost that Hainan households and businesses will pay to light their homes and run their industries; (4) reduces the future coal import bill; and (5) improves the prospects for export industries. The focus of this strategy is to adapt proven policies and techniques, including incentive-

Fig. 3.5. Summary of costs and need for additional water under the major alternatives considered in the Lower Mokelumne River Project Draft Environmental Impact Statement. (EBMUD = East Bay Municipal Utilities District; CDFG = California Department of Fish and Game.)

based conservation and efficiency for producing and using energy more efficiently, to existing conditions in Hainan.

Using information on the Hainan situation as a starting point, the report presents a plan for applying the principles of IRP and the experiences in other countries to outline a strategy for the Hainan Province. Table 3.1 summarizes the potential effects of selected DSM programs on Hainan's electric power system in the year 2000. Projected electricity demand for the year 2000 is based on the Hainan government's forecast in its eighth Five-Year Plan. The data indicate that estimated electricity savings from implementing DSM programs are substantial. Assuming a 0.6 load factor, the 1139 GWh of *energy* savings from the DSM programs in the year 2000 translates into 217 MW of *capacity* savings, which represents nearly 80% of Hainan's 1992 peak electricity demand. Assuming an avoided coal-fired unit with a \$1000-per-kilowatt capacity cost, the 217 MW of capacity savings translates into a \$217 million monetary savings. Assuming \$2000 per kilowatt, these savings increase to \$434 million, or more than one-fifth of Hainan's 1992 gross domestic product.

The data in Table 3.1 understate the benefits of implementing these programs. First, because of data and time constraints, staff members were not able to consider the full range of DSM possibilities and their interaction. For example,

Table 3.1. Summary of potential savings from selected demand-side management measures in Hainan, China, for the year 2000

Sector demand (GWh)	Forecast in 2000 ^a	Energy savings ^b	
		(%)	(GWh)
Households	414	25	103
Commerce	650	25	162
Industry	4,368	20	873
Total energy (GWh)	5,432	21	1,139
Total capacity savings (MW) ^c			217
Total monetary savings (\$ million), assuming			\$217
\$1,000 per kilowatt ^d			\$434
\$2,000 per kilowatt ^d			

^aBased on Hainan's eighth Five-Year Plan.^bIncludes only the energy savings, not social and economic benefits (e.g., environmental benefits, macroeconomic benefits, export promotion).^cAssuming a 0.6 load factor.^dThe cost per kilowatt of constructing a 200-MW coal plant in Hainan.Source: L. J. Hill et al., *A Prefeasibility Study of Energy Resource Options in Hainan, China*, ORNL/TM-12182, Oak Ridge National Laboratory, October 1992.

staff did not quantify the effects of using cost-based electricity pricing as a DSM strategy. Second, staff did not quantify the macroeconomic benefits of implementing DSM programs. In fact, one of the study's two recommendations is that Hainan authorities explore the possibility of developing a Center for Export Technologies, which would be a test bed for developing energy-efficient technologies and adapting them for use in mainland China and other Southeast Asian countries. Such a center eventually could lead to development of a significant export industry. Another important macroeconomic benefit arises from the lower electricity costs resulting from implementation of the program. Besides the obvious benefits to customers in Hainan, lower electricity costs have the added benefit of making investments in Hainan's industries more attractive to foreign investors. Finally, although the study does not quantify the environmental benefits of *not* burning coal, those benefits could be substantial.

The other major recommendation of the study is that these DSM interventions be analyzed in depth using the principles of integrated energy planning within the context of Hainan's current electric-power delivery system, its expected growth in demand, and conventional

generating options. This initiative would require (1) making a commitment to training, (2) gathering information on Hainan's electricity customers and their consumption habits, and (3) comparing the characteristics of demand and supply resources. These activities could be conducted jointly with other research organizations in China.

3.3.3 Modeling and Technology

Projects and activities in economic modeling and technology research include model development and expert review, manpower studies, new technology, and strategic energy reserves. Important activities this year have been (1) developing new model prototypes for assessing risk associated with filling and using the U.S. Strategic Petroleum Reserve (SPR) and (2) applying multivariate regression methods to identify important impact factors associated with the Commonwealth Energy System (COM/Electric) commercial client investment program.

The SPR is a government-owned stockpile of crude oil intended to serve as a buffer against possible oil market disruptions. This research project initially investigated the costs and benefits of expanding the U.S. strategic stockpile of

crude oil from 700 million to 1 billion barrels and the feasibility of a regional gasoline reserve. In the first half of this year, the project focused on the benefits from increasing the drawdown and distribution capability of the SPR. In a study by Trumble and Lee,² two models (DISSPR and ORNLTEIS) were used to compute the expected benefits of alternative drawdown and distribution capabilities. The analysis took into account the probabilities of oil supply disruptions, the availability of other sources of supply to offset the disruption, the elasticities of oil demand, and other market parameters. Assuming a 1-billion-barrel reserve and a 6-month disruption or longer, then expanding the sustained drawdown and distribution capability beyond 5.5 million barrels per day is unwarranted, simply because the reserve would be exhausted in 6 months at that rate. Therefore, conclusions regarding the value of drawdown rate expansion strongly depend on assumptions regarding the expected length of disruptions and on the likelihood of multiple, large disruptions in succession.

In a series of short experiments,³ the DOE SPR planning model DISSPR was simulated to generate statistics on the frequency and magnitude of expected drawdowns. These results highlighted some limitations of the DISSPR model in cases where disruptions are somewhat less rare than assumed in the January 1990 interagency SPR study. Given the structure of the DISSPR model, the time required for SPR refill and the value of hedging against future disruptions are not accounted for fully. Consequently, DISSPR results are more supportive of higher drawdown rates, and DISSPR associates less value with sheer size/capacity expansion.

The large uncertainty surrounding future oil market conditions and the resulting uncertainty regarding SPR program benefits have always been critical SPR planning issues. Recent project efforts have emphasized developing new ways

to portray this uncertainty or risk explicitly and flexibly. One goal is to provide a comparatively simple, graphically oriented modeling system with which SPR planners may explore these matters directly. The design of such a model has already been proposed.⁴ A working version, called SPR-Risk, was created based on the DISSPR model. The SPR-Risk model provides a simple summary of the SPR behavior and results obtained from some of the larger SPR models (DISSPR, ORNLTEIS, and Hogan-Leiby), embed-

ded in a framework that highlights risk and uncertainty. The method of response surface modeling is being applied to summarize the larger SPR planning/optimization models. Initial policy experiments will begin in FY 1993.

In the COM/Electric capital-investment test program, comprehensive lighting retrofits were installed in customer facilities to evaluate the potential for lowering energy costs as well as reducing the commercial-sector demand for electricity. David Trumble and Michael MacDonald used multivariate regression methods to model net program savings from the multimillion dollar investment program. They explored factors affecting program performance, including investment level, building size, location, weather, and economic factors.

The sample for this impact evaluation was large; the initial pool of about 1700 treatment facilities represented about 85% of the approximately 2000 facilities treated under the program during the period August–December 1990. Attrition of the treatment pool due to data gaps and metering changes reduced the final sample to about 50% of all buildings treated during the period of interest. To improve comparability and overall results, a control group was selected from facilities that are on the waiting list for this program. Although the control group was much smaller, with about 260 facilities, little attrition was experienced.

The large uncertainty surrounding future oil market conditions and the resulting uncertainty regarding SPR program benefits have always been critical SPR planning issues.

Energy savings for this program were estimated using both simple, aggregate data and two-stage building-specific parameter modeling. The aggregate data provided important insights into program performance, and the two-stage regression modeling helped reduce variability in results. Overall, the impact evaluation results indicate that the net program investment-cost ratio (the ratio of total costs to net electricity savings) is close to \$0.60/kWh when weather and cost factors are included. Economic factors were included in savings estimates, but the results indicated either data endogeneity or high variance problems, so economic effects are not estimable for the data set on this small program with the methods used here.

Savings estimates based on simple, aggregate annual results (which are typically used for impact evaluations of programs) indicate that this investment ratio is about \$0.55/kWh, which is similar to the previous aggregate results reported in the phase 2 evaluation. The building-specific model that corrects for weather (model 3) also indicates that the net investment-cost ratio is about \$0.55/kWh (\$0.51–\$0.60/kWh). Thus, several modeling approaches have indicated that the net investment-cost ratio for this program is about \$0.55–0.66/kWh.

3.4 RESEARCH UTILIZATION

Like the projects described here, most EEAS research contributes directly to planning, policy, and analysis activities of public agencies. The research focuses predominantly on sponsors' needs and normal avenues of use. For example, DOE uses the petroleum-modeling studies to assist in SPR planning activities. Information and analysis developed for the Energy Information Administration support its data and information activities, including the Secretary of Energy's report to Congress on the uranium industry, the National Energy Strategy, and the Annual Energy Outlook. Studies on energy conservation and impacts are used by DOE, the U.S. Department

of the Interior, and other agencies to understand energy retrofit decisions. Other agencies that use EEAS research results in program planning and analysis include the Federal Emergency Management Agency, Bonneville Power Administration, EPA, the U.S. Department of the Air Force, the U.S. Department of the Navy, and the U.S. Agency for International Development.

Though the primary objective of EEAS research is to solve individual sponsors' problems, the research is by no means limited to those purposes. The section's mix of economics research projects for DOE and work-for-others sponsors, conducted in a laboratory environment, provides a multidisciplinary forum in which many technical and social aspects of individual problems are identified. These findings contribute ultimately to an understanding of complicated social and economic systems and become incorporated into solutions for general energy-related issues of national importance, such as the global increase in CO₂, stratospheric ozone depletion, and energy for development of third-world nations.

3.5 REFERENCES

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C e n t e r f o r T r a n s p o r t a t i o n A n a l y s i s

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CENTER FOR TRANSPORTATION ANALYSIS OVERVIEW

4.1 INTRODUCTION

The Center for Transportation Analysis (CTA) conducted a diverse mix of research activities in 1992, reflecting the year's major social and political upheavals at both national and international levels. For the U.S. Department of Defense (DOD) transportation agencies, CTA staff members continued to develop planning tools needed for the highly mobile defense forces required in the post-Cold War world. On the increasingly important domestic agenda, CTA is prepared to play a major role in improving the highway infrastructure, a centerpiece of President Clinton's successful election campaign. Center staff will also continue to provide the environmental background information required for realistic and effective energy-policy decisions by the new administration.

To complement their targeted development efforts such as the AMC Deployment Analysis

System and Intelligent Vehicle Highway Systems (IVHS) work, CTA staff members also carried out research devoted to enhancing and validating nationally important data bases such as maps of the nation's transportation networks and records on the composition of our nation's vehicle fleet. This research is essential to policymakers at local, state, and national levels, and staff experts serve the nation as members of commissions and committees working for the U.S. Departments of Energy (DOE) and Transportation (DOT). Much of the research, which crosses disciplinary boundaries, is carried out in collaboration with other staff both at Oak Ridge National Laboratory (ORNL) and outside the laboratory.

CTA's military transportation research and development focuses on new techniques for planning and executing strategic deployment of personnel and materiel. Tools developed by the center's staff continue to serve the military agencies responsible for deployment of U.S. forces.

Based on a solid foundation of operations research theory, these new tools incorporate the practical knowledge of the center's staff members, who have developed a base of expertise spanning several branches of the armed forces and various transportation media.

4.2 POLICY ANALYSIS AND CONSERVATION

The center continues to fulfill a major role as an information resource for policymakers who consider the impacts of transportation on the nation's economy and environment. Again this year, the center gathered and analyzed data and published reports about many aspects of the nation's transportation network and vehicle fleet.

4.2.1 Transportation Planning and Policy

CTA transportation research covers all modes but pays particular attention to highway transportation, which accounts for more than 73% of the nation's energy used for travel. ORNL continues to lead in the development of an extensive national highway network data base, containing roadway lengths, traffic capacities, and other statistically and operationally useful planning characteristics for more than 400,000 miles of road. In 1992, CTA began a concerted effort to add national rail, waterway, crude and product pipeline, and air-freight transportation networks to its award-winning national highway data base, and to extend such networks into Canada and Mexico. These networks, together with the location of intermodal transfer points, create a data base that will soon be used to support the Bureau of Transportation Statistics and the Census Bureau in their analysis of the 1993 Commodity Transportation Survey. Figure 4.1 indicates these networks schematically. Most likely single- and multimodal commodity transportation paths can be generated between any pair of U.S. zip code locations—a level of detail far exceeding previous attempts to do this,

which date back to 1977. (Approximately 48,000 zip codes cover the continental United States.)

CTA staff members have undertaken a major Geographic Information System (GIS) initiative in support of these transportation planning methods. In conjunction with staff at the University of Tennessee's Transportation GIS Laboratory, CTA has developed procedures for matching every link in the multi-attribute national highway planning network to a series of more accurate geographic coordinates based on the digital line graphs supplied by the U.S. Geological Survey. This innovative network-matching algorithm will result in a new national highway network with accuracy of link locations improved from the 1:2,000,000 to the 1:100,000 scale. As part of this same project, the nation's latest state, congressional district, county, and coastline boundaries have been remapped. A third stage of the project now under way involves the mapping and redesignation of each state's principal urban arterials, as well as redesignated urban area boundaries, for places with populations over 50,000.

The culmination of this effort will be not only much more accurate maps of the national highway system, but also a much improved network data base for use in a variety of analytic studies. For example, CTA is currently assisting the Federal Highway Administration (FHWA) with research on alternative national highway network designs, using criteria such as population coverage, volume of traffic moved, and the interregional allocation of network miles. Workstation-based software is being developed into a comprehensive spatial decision support system for comparing two or more candidate 2020 highway networks, from whatever source generated. Procedures for generating candidate networks range from manual procedures that add or delete specific links or routes, to automated and highly innovative algorithms that approximate large optimal network designs.

Various federal agencies are sponsoring a conceptually similar effort to develop a national waterway network. CTA staff members and contractors will draw data from several existing data bases—both geographic and nongeographic—and integrate them into a geographically oriented representation of the nation's waterways.

Fig. 4.1. National highway, rail, waterway, and air-freight transportation networks like these will be used to analyze the 1993 Commodity Transportation Survey.

These CTA efforts will use automated network-matching techniques originally developed to resolve problems associated with the national highway networks.

4.2.2 IVHS Project Office

In 1992, the center established a new group known as the IVHS Project Office, recognizing ORNL's growing interest in and involvement with this initiative. Through an interagency agreement, CTA's planning and policy group is providing technical assistance and program support to FHWA for its IVHS research program. ORNL staff members are serving as a technical resource to FHWA/DOT in carrying out this IVHS initiative and are also conducting specific studies associated with the program. The current scope of ORNL's IVHS work includes a number of research, analysis, and technical support activities, including the development and definition of technical approaches; the identification of research needs and program priorities; the evaluation of research proposals and ongoing research projects; the conduct of preliminary analyses and reviews; the development and

testing of system prototypes; the organization and conduct of conferences and professional forums; the promotion of industry, government, and academic partnerships; and the organization of common data and information resources.

The CTA IVHS team is providing research and analysis support to FHWA in two primary technology clusters that deal with commuter mobility: Advanced Traffic Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). ATMS involve the management of traffic on highway networks comprising freeways and surface streets in an integrated, real-time, and fully adaptive fashion. ATIS provide in-vehicle information through a combination of sensors, on-board computers, and communications links with centralized traffic-operations centers. Several studies and support activities currently under way as part of ORNL's work on IVHS include

- assessment of benefits from in-vehicle navigation systems;
- IVHS program support;
- participation in IVHS America activities, a federal advisory committee;

TRAFFIC SIGNAL OPTIMIZATION USING MAXBAND

MAXBAND is a widely used computer program for optimizing signal settings in unsaturated traffic conditions in urban street networks. Originally developed at Massachusetts Institute of Technology in the mid-1960s, it has been occasionally updated to handle additional real-world situations. The current version, MAXBAND 86, optimizes cycle time, offsets between signals, and the left-turn phase sequences. However, a test of the program in a personal-computer (PC) environment by the Federal Highway Administration revealed numerical problems that led to incorrect results.

Researchers in the Center for Transportation Analysis resolved these numerical difficulties in the PC version by determining the suitable values of the tolerance parameters used by the program's optimization logic and rescaling a variable in the problem formulation to alleviate the numerical instabilities.

Large urban networks require an excessive amount of computation time in arriving at the optimal solution. A promising heuristic has been developed that generates near-optimal solutions in a fraction of the time. The heuristic is currently being evaluated on realistic data sets for possible full-scale implementation. ♦

- development of evaluation procedures for IVHS projects;
- the MAXBAND Signal Optimization Program;
- a special report on traffic flow theory;
- TRAF simulation model prototypes;
- a fuel consumption and emission study;
- assessment of benefits of traffic models;
- feasibility of ATMS/ATIS Traffic Control Center Simulator (phase 1: general assessment); and
- cost estimates for deployment of ATMS.

In addition, discussions are currently under way to start several other specific research activities. CTA staff members will continue to assist FHWA in developing state-of-the-art traffic modeling and analysis systems, decision-support systems, human-factors studies for IVHS, fuel consumption and emission studies, and laboratory testing and evaluation of IVHS concepts. As required by FHWA, CTA staff members will conduct basic research in the area of traffic flow theory and operations. Currently, ORNL staff members are working with three separate offices of FHWA.

Successful design, development, and implementation of IVHS will also require an in-depth understanding of the basic theories of traffic flow. Of significant interest to ORNL research staff and the traffic flow theory research community is revision of the *Transportation Research Board's (TRB's) Special Report 165 (SR 165)*. This report contains an excellent synthesis of work in the area of traffic flow theory and characteristics and is widely referenced by researchers and practitioners alike as perhaps the best reference in this subject area. Originally published in 1965, this report was last revised in 1975. Therefore, many topics in the special report need major revisions. Knowledge of fundamental traffic characteristics, theories, and associated techniques is an essential requirement in the planning, design, and operation of transportation systems.

FHWA has asked ORNL to revise SR 165 by incorporating research performed since 1975. In doing so, ORNL will work closely with TRB's Committee on Traffic Flow Theory and Characteristics (A3A11). A subcommittee has been established by TRB to assist ORNL in developing

an outline of the revised report, identifying the teams that will write the individual chapters, identifying the team leaders, developing work-plan/assignments for each team, estimating the required level of effort, and reviewing each team's draft manuscripts. The SR 165 Update will be an academically interesting yet administratively challenging task. ORNL staff members will work with 8 to 10 academic teams in developing a much needed revision to this text in traffic flow theory.

In the first 6 months of work on the IVHS project, CTA staff members have made important technical contributions to FHWA's contract plan

ORNL-Photo 1460-93

Ajay Rath leads work on Intelligent Vehicle Highway Systems.

for FY 1992 through FY 1994 and have conducted important technical studies, including

- Participation on the evaluation panels for several major research projects in the areas of traffic modeling, operations, and human factors.
- Development of a generic evaluation framework for the IVHS project.
- Improvement of the MAXBAND optimization model to stabilize its performance on a microcomputer environment. MAXBAND is a popular traffic-optimization model known to be numerically unstable on personal computers when the problems involve selecting an optimal cycle time from a range of cycle times (see highlight, "Traffic Signal Optimization Using MAXBAND").

- Assessment of the potential benefits of in-vehicle navigation and information systems using computer simulation.
- Input to the IVHS strategic and tactical planning process through its affiliation with IVHS America. ORNL represents the interests of the national laboratories in the IVHS research, development, and deployment agenda. Partly because of ORNL's involvement with these activities and past work for FHWA, the national laboratories are identified as having a significant technical asset that can be used effectively in a national IVHS program.
- Assistance to FHWA in developing research programs for FY 1993 and beyond.
- Reviews of several important, on-going studies, including real-time traffic adaptive signal control systems, network-wide optimization models, dynamic traffic assignment models, support systems for ATMS, and a traffic management laboratory/simulator.

IVHS is a truly interdisciplinary effort at ORNL. Currently, research staff members from three different divisions and from several universities are collaborating on IVHS project activities.

4.2.3 Motor Vehicle Fuel Economy and Emissions

The center continued its leadership in the analysis of costs and benefits of increasing automotive fuel economy. A detailed analysis completed this year includes quantitative consideration of such diverse aspects as conservation technology safety effects and the transfer of wealth from U.S. consumers to oil producers. Net benefits were strongly influenced by assumptions about discount rates and values of environmental and energy security effects. The study showed generally positive net social benefits for new car fuel-economy levels up to 36 miles per gallon (mpg) and light truck levels up to 27.5 mpg. Only proven technologies, those currently used in mass production vehicles, were considered in the analysis.

REFORMULATED GASOLINE: COSTS AND REFINERY IMPACTS

During 1992, researchers at the Center for Transportation Analysis provided analytical support to the U.S. Department of Energy Office of Energy Demand Policy in assessing costs and impacts of the gasoline quality requirements of the Clean Air Act Amendments of 1990 (CAAA). The CAAA will affect petroleum refining more than any other industry because, in addition to complying with all other CAAA provisions, refiners will have to modify, design, permit, and construct new units to produce mandated clean fuels such as reformulated gasolines (RFGs).

For RFGs, the law specifies a minimum oxygen content, a maximum benzene content, maximum summer Reid vapor pressures (RVPs), no heavy metals, no increase in nitrogen oxide emissions, and reductions in emissions of ozone-forming volatile organic compounds (VOCs) and toxic air pollutants. The CAAA will require a formal fuel certification procedure for demonstrating the emissions performance of a gasoline. Emissions modeling provides a means for predicting a gasoline's emissions performance, given other physical and chemical properties of the gasoline.

The Complex Model will be a set of equations that predicts emissions in terms of the values of a number of gasoline properties. A preliminary Complex Model published by the U.S. Environmental Protection Agency in October 1993 included the gasoline properties of RVP, T50, T90, benzene, oxygen, sulfur, aromatics, and olefins contents.

Studies of RFG costs and refinery impacts have been performed with the Oak Ridge National Laboratory Refinery Yield Model (ORNL-RYM), a linear program that has been updated to blend gasolines to satisfy emissions constraints defined by pre-

liminary complex emissions models. Non-linear emissions models have been represented in ORNL-RYM by assuming that an emission value can be represented as a base emission value plus small linear emissions changes due to small changes in gasoline properties.

The updated ORNL-RYM has been used to estimate costs and refining impacts for producing RFGs in the U.S. East Coast Petroleum Administration for Defense District (PADD I) and U.S. Gulf Coast (PADD III) (Figs. 4.2–4.4). For 100% production of RFG in PADD I during summer of the year 2000, the estimated reformulation costs increase moderately with VOC reductions of between 20% and 30%. Reformulation costs are 9.0 cents per gallon at 20% VOC reduction and 15.2 cents per gallon at 30% VOC reduction. Reformulation costs increase rapidly to the right of a cost knee with VOC reductions of somewhere between 30–32%. RVP reduction is the dominant VOC reduction mechanism. At high levels of VOC reduction, larger process capacity additions include fluid catalytic cracker (FCC) feed hydrofining, FCC gasoline fractionation, alkylation, ether pro-

Fig. 4.2. PADD III reformulation cost vs volatile organic compound (VOC) reduction.

Fig. 4.3. PADD III gasoline Reid vapor pressure (RVP) vs volatile organic compound (VOC) reduction.

duction, and feed preparation for alkylation and etherification.

For the production of 50% RFG and 50% conventional gasoline in PADD III during summer of the year 2000, the estimated reformulation costs (Fig. 4.2) range from 3.6 cents per gallon (at 20% VOC reduction for RFG) to 15.4 cents per gallon (at 42% VOC reduction). Reformulation costs begin to increase rapidly after the RVP floor of 6.5 psi is reached (Fig. 4.3), at a cost knee for RFG VOC reduction somewhere between 35 and 40%. Even with antidumping constraints, conventional gasoline appears to be an important dump that permits RFG to be blended with lower aromatics (Fig. 4.4) and lower sulfur contents. At high levels of VOC reduction, capacity additions include FCC gasoline fractionation, ether production, and feed preparation for alkylation and dimersol/polymerization units.

In addition to the potentially large sensitivity of RFG production to different emissions models, RFG production is sensitive to the nonexhaust VOC share assumption for a particular VOC model. ORNL-RYM has also been used to estimate the sensitivity of RFG production to the cost of capital, to the RVP requirements for conventional gasoline, and to the percentage of RFG produced in a refining region.

Policymakers may use the reformulation cost knee as a reference for setting emissions-reduction targets. ORNL-RYM estimates that the reformulation cost knee for PADD I is about 15.2 cents per gallon with a VOC reduction of 30%; the estimated cost knee for PADD III is about 5.5 cents per gallon with a VOC reduction of 35%. ♦

Fig. 4.4. PADD III gasoline aromatics vs volatile organic compound (VOC) reduction.

In a related study, center staff members and collaborators from the University of California Institute of Transportation Studies are exploring the effectiveness of fuel-economy improvements to reduce harmful emissions of hydrocarbons into the atmosphere. In their study, the authors consider volatile organic compound (VOC) emissions throughout the fuel production and

use cycle, from oil well to vehicle exhaust. They conclude that strategies to improve vehicle fuel economy are also effective in controlling hydrocarbon emissions (perhaps as effective as other proposed emission-control measures); furthermore, such strategies are essentially free when the fuel-economy improvements are otherwise cost-effective.

4.2.4 Petroleum Refining

In support of the DOE Office of Energy Demand Policy, CTA researchers used the ORNL refinery linear program to study the impacts of the Clean Air Act Amendments (CAAA) of 1990 on U.S. petroleum refining. In an early analysis, CTA estimated that the total added costs for reformulated gasolines could be in the range of 5 to 8 cents per gallon, a result closely matched a year later in a major study of U.S. refining by the National Petroleum Council.

The CAAA will impose constraints on vehicular emissions of VOCs, nitrogen oxides, and toxic compounds. Gasoline emissions will be estimated by models that will include the effects of oxygen, aromatics, benzene, sulfur, olefins, and gasoline distillation properties. CTA took a lead role in the incorporation of multivariable, nonlinear gasoline-emissions models into refinery linear programs. The ORNL refinery linear program was used to estimate the effects of gasoline emission constraints on the production costs and quality of gasolines (see highlight, "Reformulated Gasoline: Costs and Refinery Impacts").

During Operation Desert Storm, in-flight refueling using the Air Force jet fuel JP-8 took place in Navy aircraft. The JP-8 fuel is specified with a lower margin of safety for accidental ignition than the Navy jet fuel JP-5. Because no standard operating procedures exist for handling JP-8 returned to Navy aircraft carriers, JP-8 or fuel contaminated with JP-8 had to be dumped. A DOD memorandum of lessons learned during Desert Storm included a recommendation to work toward a common military jet fuel. In 1992, CTA prepared the ORNL refinery linear program to estimate the availability and cost impacts of a jet fuel that will satisfy the freezing and flash point requirements of all military services.

4.2.5 Alternatives for the Panama Canal

The center's research often extends beyond U.S. boundaries and impacts transportation at the international level. One example of international commitment this year involves the Panama Canal, a critical link in international

commerce. The canal frequently operates at or near full use, and a commission has been established to study plans for improvements or alternatives to the 77-year-old shipping link. A private organization, TAMS Consultants, Inc., has been awarded a contract to study operating characteristics and their relation to the capacity of the canal. TAMS will consider 19 alternative configurations, including the canal as it exists, proposed improvements to the canal, and a proposed sea-level canal. TAMS, in turn, has asked CTA for assistance in developing and using computer models to simulate operation of the proposed alternative versions of the canal.

Center staff members and their consultants will analyze current operations of the canal to prepare realistic input data for the Waterway Analysis Model (WAM), the standard computer tool for predicting water network traffic and capacity. For some specific characteristics of the Panama Canal and the proposed alternatives, CTA will need to revise and extend some components of the model. WAM will then be run to forecast the behavior of canal traffic for alternative configurations of the canal in the years 2020 and 2060, or until the model indicates that capacity is reached. These results will facilitate the plotting of delay curves for each alternative and will lead to the ultimate choice for upgrading the canal.

4.3 METHODS AND DATA

CTA continues to take a national lead in the compilation, maintenance, and analysis of transportation data. In 1992, the National Highway Traffic Safety Administration of DOT asked the center to develop analytical approaches to provide scientific evidence of age-related physical and mental limitations in older drivers in relation to highway safety. Another CTA project stemmed from previous work for FHWA. A statistical model developed to determine relationships between highway geometry and truck accidents is being refined to address safety issues associated with specific roadways (e.g., rural, undivided 4-lane highways). Other examples illustrating CTA's leadership in 1992 include the publication of two major collections of transportation and

energy statistics, the *Transportation Energy Data Book* and the *Highway Vehicle MPG and Market Shares Report*, and the compilation of two publications on freight movements and personal travel, the *1990 Nationwide Truck Activity and Commodity Survey Summary Report* and the *1990 Nationwide Personal Transportation Survey: Summary of Travel Trends*.

4.3.1 Highway Safety

Older Drivers and Highway Safety

American society is undergoing a major demographic transformation that will continue into the next century. At the beginning of this decade, only 1 in every 25 persons in the United States was 65 years of age or older. By 1984, about 1 in 9 persons was 65 or older. According to the U.S. Bureau of Census, if birth rates stay low, 1 of 5 persons in the United States will be 65 or older between 2020 and 2030. Furthermore, the number of older persons licensed to drive continues to increase steadily. Although older drivers travel fewer miles than the rest of the population, they drive more miles than their same-age counterparts of past years. The graying of America has captured the attention of policy-makers and researchers, and the balance between the mobility and safety of older drivers has become a crucial social issue.

In 1986, Congress passed the Surface Transportation Act, calling for a TRB study of the safety and mobility of older drivers. Results from this study call for reevaluation of the license screening and testing practices to better identify older drivers who have physiological and psychological functional impairments that affect their ability to drive safely.

Much research has been devoted to examining older drivers' driving behavior, age-related physiological and psychological changes, accident patterns, and involvement rate in traffic accidents. However, little has been done to establish scientific evidence to link age-related functional and mental limitations to driving performance in terms of traffic crashes and moving violations. CTA's involvement in this highway safety area includes developing an analytical

approach that uses existing epidemiological and medical data bases to statistically link age-related functional impairments and increased highway risk. The link(s) will be crucial in assisting licensing agencies to adopt regulations for older drivers.

Large Trucks and Geometric Design

The Surface Transportation Assistance Act (STAA) of 1982 preempted more restrictive state vehicle size and weight limits. STAA has allowed longer and wider trucks to travel on designated national highways. Safety questions, such as whether the current highway design is adequate to serve these larger trucks and what highway geometric design variables pose the most serious safety problems for large trucks, are important public and government concerns. Occurrences of vehicle accidents, however, have long been recognized as complex events involving the interactions of many factors, including road and vehicle characteristics, drivers (human factors), traffic, and environment (e.g., weather and lighting conditions). Previous attempts to establish relationships between truck accidents and highway geometric design variables have produced mixed results, and no specific relationships are widely accepted.

During 1991, FHWA initiated a two-phase process to study this geometric design/truck accident relationship. CTA's Statistics and Data Analysis Group has participated in phase I of the process. Objectives included (1) identifying a statistical framework with desirable properties to establish relationships between truck accidents and highway geometric design; (2) developing preliminary models, based on the identified statistical framework, using recent and more detailed data from existing data sources; and (3) suggesting areas in which the quality and quantity of existing data can be enhanced to improve the developed models. This phase I work was completed at the end of November 1991. Based on results and recommendations from phase I, CTA has continued to refine the statistical models for more specific roadways.

4.3.2 National Transportation Surveys

Several projects are currently under way for DOT's FHWA as a result of the *Statement of National Transportation Policy* (NTP) by DOT. NTP identified a wide range of issues and policies related to the collection, processing, and distribution of transportation data and clearly stated that the federal government's policy is to identify national needs for information on transportation. This year, the center played a significant role in two major national transportation data collection and distribution efforts:

(1) The *1990 National Personal Transportation Survey* (NPTS) collects information on the travel behavior of the nation's population. Detailed travel patterns were collected according to trip purpose and mode of transportation. In 1990, the NPTS interviewed 22,000 households, including detailed information on more than 92,000 vehicle trips and 146,000 person trips. A summary of travel trends was published in March 1992, with a circulation of 10,000 copies. A four-volume report series is planned for release in 1993 that includes detailed survey results. Results from the previous NPTS and the 1990 survey indicated that the average size of American households was decreasing, that American households owned more vehicles, and that more and longer daily vehicle trips resulted in a significant increase in daily households' driving (as expressed in vehicle miles of travel). Figure 4.5 illustrates trends for some demographic variables and travel statistics over time.

(2) The *1989 Nationwide Truck Activities and Commodity Survey* (NTACS) obtains additional information on commodities carried, basic commodity flow information, and safety features. The center's involvement included an evaluation of the survey design, a determination of priorities to allocate available resources most efficiently, and the development of statistical methods to establish the link between the *Truck Inventory and Use Survey* (TIUS) and NTACS.

To fill the information gap on the nation's fuel-use patterns, the center is also undertaking several projects to estimate fuel consumption in the public sector and in off-highway activities with scarce data. In addition, the center is participating in the planning of several national surveys—the 1992 TIUS and NTACS, as well as the *1993 Commodity Flow Survey*.

4.3.3 Transportation Energy Data Book

The *Transportation Energy Data Book* is a statistical compendium prepared and published for DOE's Office of Transportation Technologies. Designed as a desk-top reference, the data book assembles statistics and information that characterize transportation activity, and presents data on other factors that influence transportation energy use. The purpose of the document is to present relevant statistical data in the form of tables and graphs. Each of the major transportation modes—highway, air, water, rail, and pipeline—is treated in separate chapters or sections. With an external distribution of almost 1000 copies this year, the *Transportation Energy Data Book* is internationally recognized as a primary source for transportation data. This publication's users include the U.S. Congress, the automobile industry (e.g., General Motors Company), numerous federal and state government agencies, regulatory boards, and foreign government and research institutes. Moreover, DOE used data contained in this publication to develop the National Energy Strategy.

Fig. 4.5. Changes in numbers of individuals and vehicles over time.

GRAPHICAL TOOLS PROVIDE INSIGHT FOR AIRLIFT PLANNERS

The AMC Deployment Analysis System (ADANS) provides the Air Mobility Command with a variety of tools for planning and scheduling the movement of personnel and cargo around the world. These movements may support day-to-day U.S. government activities or training for U.S. troops, or the movement may be in response to a crisis, either a natural disaster or a military threat. One of the scheduling tools is a dynamic programming-based automated scheduler. In less than a second, this component will create a detailed itinerary for a mission that will not conflict with the current commitment of aircraft and ground resources, or it will determine that the movement is infeasible. The planner can monitor the progress of the system through a graphical interface

(Fig. 4.6). In this example, the system displays a network of possible routings from the chosen plane's current location at RODN (each airfield is identified by a unique international 4 character code) to the pick-up location for the cargo, KTCM, on to the off-load location, RPMK, and finally to a maintenance facility at either RODN or PGUA. The conflict preventing the movement is displayed in the bottom half of the screen where resource availability is displayed for the flight from PGUA to RPMK. The flight is infeasible because the plane would arrive during the time the airfield is closed. This type of interface provides the planner with a view into the logic of the scheduling routine and prevents the system from becoming merely a "black box." ♦

ORNL-Photo 408-92

Fig. 4.6. Sample screen from the AMC Deployment Analysis System showing graphical interface.

4.4 MILITARY PLANNING AND SCHEDULING SYSTEMS

Researchers in CTA and its predecessor organizations have worked closely with military traffic planners for over 10 years, developing extensive and unique expertise in a broad spectrum of military transportation arenas. Working from solid foundations in operations research and computer technology, the center's staff members have helped military agencies solve transportation problems so large that they dwarf most civilian movement issues (see highlight, "Graphical Tools Provide Insight for Airlift Planners").

4.4.1 FAST Planning for TRANSCOM

The Flow and Analysis System for TRANSCOM (FAST) is a military deployment analysis tool being developed by CTA staff members to help determine transportation requirements, analyze alternate courses of action, and estimate arrival of troops and equipment traveling by air and sea into an overseas theater of operation. FAST is sponsored by the U.S. Transportation Command, which is responsible for all common-carrier services in DOD. An early version of this system was used in Operation Desert Shield to predict the number of airplanes and ships needed to send U.S. forces to the Middle East. Transportation estimates developed by FAST helped establish the deployment's concept of operation, including timing for offensive operations. After the flow began, the system was used to track ships, provide delivery forecasts, and analyze "what-if" scenarios such as canal closings and maintenance delays.

The analysis models in FAST are based on those used by DOD agencies responsible for managing transportation during actual deployment. Thus, the system is not just another transportation model, but one that produces the same answers as the full-scale estimation tools used by the operators responsible for strategic airlift and sealift during a contingency.

Brian Jones, Pete Schmidt, and Anurag Agarwal (from left) of FAST.

The capabilities of FAST are now widely recognized by DOD transportation agencies and unified commands (responsible for theater operations) throughout the world. The Military Sealift Command has purchased equipment necessary to use the system in their sealift operations, and the Military Traffic Management Command (MTMC) has expressed interest in using FAST as a basis for analysis tools in their Crisis Action Center. The Joint Staff is now installing the system in all unified commands for developing war plans and monitoring redeployment during exercises and real-world operations.

FAST provides extensive capabilities for determining needed transportation assets (e.g., planes, ships, or port capability), how transportation requirements must be time-phased so that trucks and trains properly meet up with aircraft and ships, and projected arrival dates of units and their equipment at destinations. Results are also used to estimate the amount of active duty military, reservists, and support from the civil sector required to meet national objectives. When a course of action is determined, the system is used to generate transportation utilization plans for trucks, trains, aircraft, and ships so that personnel arrive at their destinations at the same time as their materiel and at rates that minimize congestion of strategic ports and en-route support bases.

4.4.2 Tracking Military Shipments

With the help of software developed by CTA staff members and subcontractors, the United States effectively moved an enormous amount of materiel to Saudi Arabia for the Gulf War. This mobilization operation was a celebrated success. Unfortunately, after winning the war, we lost much expensive equipment and supplies on the way home. Loss estimates vary, and it may be almost impossible to account for all of the goods shipped out, partly because shipment records were contained in many different, incompatible computer systems.

MTMC recognizes this problem, and it also recognizes that CTA staff members have the technical expertise and transportation knowledge to help solve the problem. Previous CTA efforts have involved development of an Integrated Booking System for military cargo, and current efforts are directed toward the design of an Integrated Cargo Data Base (ICDB). The objective is to ensure that MTMC's needs for data sharing and systems integration can be met. ORNL will assist MTMC personnel in developing the ICDB. Once completed, the ICDB will receive and manage data from multiple systems, provide information to various MTMC and non-MTMC systems and organizations, and support

ORNL-Photo 1059-93

Mike Hilliard and Irene F. Robbins lead work on the AMC Deployment Analysis System.

worldwide oversight of surface cargo that passes through common-user ocean terminals. The ICDB will be responsible for data management, data distribution, communication, inquiry, and reports production. CTA support will include analysis and design tasks, documentation, and systems integration.

The problems addressed in this task include data quality control, real-time report production from a relational data base, and effective/efficient presentation of inquiry responses. Various state-of-the-art technical approaches, such as distributed data base technology, are being considered in planning for this complex data base management system.

ORNL is responsible for data base and overall system design and is coordinating actual system production activities among MTMC Headquarters, MTMC Eastern Area, and MTMC Western Area commands. Thus, technology transfer is a major responsibility of the project.

4.5 DECISION SUPPORT SYSTEMS

4.5.1 A Demand-Side Management Program Evaluation Expert System

CTA staff members have developed a prototype expert system called EVAL. This system assists users in developing evaluation designs for demand-side management programs. This project is being funded by the Electric Power Research Institute (EPRI) and DOE.

4.5.2 Reliability-Centered Maintenance

Center staff members with significant recent experience with the Bonneville Power Administration (BPA) grid have been asked to undertake a multiyear project to help BPA implement a reliability-centered maintenance (RCM) program. RCM techniques have the potential to improve the quality of maintenance of electrical and mechanical equipment and simultaneously reduce maintenance costs.

Electric utilities recognize the need to improve their maintenance procedures on high-power electric-transmission equipment. The average age of electric-power equipment is increasing; as this equipment ages, maintenance must be performed more meticulously. When monitoring instrumentation is added, the existing health of equipment can be determined, and maintenance can be performed on an as-needed basis rather than on fixed-time intervals. Benefits for a utility like BPA can reach \$8 million a year.

The RCM project has just completed its second year. The first year produced a feasibility study. This second year, a monitoring system was installed at BPA's Alvey substation. A breaker monitor was also developed by ORNL to support RCM. Instrumentation was connected to two of BPA's 230-kV breakers and a 500-230-

kV transformer. The instrumentation is reporting its values to a user-friendly graphical interface. Data are converted to information so BPA personnel can quickly determine the equipment's condition. Results from RCM were received favorably at an EPRI workshop on advanced substation equipment diagnostics held in November 1992.

CTA has two primary objectives for this coming year. One is to extend the monitoring instrumentation to the remainder of the transmission equipment at Alvey substation. The other is to add diagnostic logic that will promote predictive maintenance. The Alvey system is a prototype that may eventually be extended to BPA's entire power system. Other utilities have expressed interest in RCM because they have many of the same concerns as BPA.

Efficiency and **R**enewables **R**esearch **S**ection

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EFFICIENCY AND RENEWABLES RESEARCH SECTION OVERVIEW

5.1 INTRODUCTION

The Efficiency and Renewables Research Section (ERRS) conducts research and implementation projects to improve the efficiency of energy end-use and delivery technologies. ERRS staff members organize and participate in cooperative activities with industry, agencies of government, academia, and international organizations. Major programs within ERRS involve energy efficiency in buildings, transmission and distribution (T&D) of electricity, development and assessment of strategies for implementing energy efficiency measures, and technical support for international programs. Buildings research includes studies of equipment such as heating, ventilating, and air-conditioning (HVAC) systems; refrigeration; district heating, cooling, and cogeneration; building envelopes and materials; and monitoring, retrofitting, and rehabilitation of existing buildings.

Electricity delivery research covers real-time power control, high-voltage direct current (dc) transmission, integration of distributed sources, power transients, health effects of 60-Hz electric and magnetic fields, and T&D policy issues. Implementation analysis includes integrated resource planning/demand-side management (IRP/DSM) and weatherization assistance programs. ERRS currently offers energy-related technical support to utilities in Eastern Europe, to the U.S. Agency for International Development (AID) missions in Latin America, and to Asian members of the Asian Pacific Energy Commission (APEC). Additional research areas include thermal environment control systems, automobile air conditioning, performance audits of buildings, and technology transfer efforts.

ERRS has expanded activities in three important areas during 1992: chlorofluorocarbon/hydrochlorofluorocarbon (CFC/HCFC) alternatives, utility T&D policy research, and inter-

national collaboration. ERRS places special emphasis on its comprehensive research on CFC/HCFC replacements. Projects include characterization of improved refrigerants for building HVAC and refrigeration systems and for auto air conditioners, alternative blowing agents for foam insulation products, and substitute heat-exchange fluids for the gaseous diffusion uranium enrichment process. Of special significance is the work now under way to find replacements for HCFC-22, which is widely used in unitary equipment. T&D policy research includes cooperative projects with the National Association of Regulatory Utility Commissioners and energy export studies. In addition, ERRS is developing strategic options to increase exports of U.S. nuclear technologies. ERRS international technical support, previously focused on support for AID in Latin America, has been expanded to include helping the U.S. Department of Energy (DOE) establish energy efficiency programs in Asia through APEC and cooperating with the Polish government to develop projects in DSM and biomass-to-energy conversion.

5.2 BUILDING EQUIPMENT RESEARCH PROGRAM

The Building Equipment Research (BER) Program at Oak Ridge National Laboratory (ORNL), sponsored principally by the DOE Office of Building Technologies, focuses primarily on the development of technology for more efficient space heating and cooling, refrigeration, and water heating equipment used in residential and commercial buildings. Environmental issues such as ozone depletion and global warming are increasingly important, and the program is contributing to the U.S. industry's transition from CFC refrigerants to acceptable, atmospherically safe alternatives that provide equal or better energy efficiency. Increased effort is being devoted to HCFC alternatives, especially for HCFC-22, which is widely used in residential and packaged commercial air-conditioning and heat pump equipment (see highlight, "Alternative Fluorocarbons Environmental Acceptability Study"). The BER program has

maintained strong ties with industry and is actively working with individual companies, industry consortia, and major trade associations to plan and conduct government/industry cooperative research and development (R&D) programs. This includes several cooperative R&D agreements (CRADAs) with industry, as authorized under the National Competitiveness Technology Transfer Act of 1989. Research sponsorship also includes the national utility research institutes, the Electric Power Research Institute (EPRI), and the Gas Research Institute (GRI). Research pursued in the BER program continues to fall within three areas: thermally activated heat pumps (TAHPs), novel cycles, and advanced refrigeration systems.

5.2.1 Thermally Activated Heat Pumps

TAHP efforts focus on promising technologies that target various heating and cooling market segments described in the National Energy Strategy (NES). Residential natural gas heat pumps to be introduced in the 1995–1996 market will offer performance that is twice the efficiency of gas furnaces and will eliminate ozone-depleting CFCs and reduce electric utility summer peak loads. Advanced "triple-effect" gas-fired absorption chillers for large commercial buildings should restore U.S. industry to a position of technological leadership and allow U.S. manufacturers to regain a significant share of a market currently dominated by Japanese double-effect chillers. Performance efficiency of these new chiller cycles now under development is 30 to 50% higher than today's commercially available double-effect chillers.

System development, component development, and supporting research activities were continued in FY 1992 on a residential generator-absorber heat exchange (GAX) absorption heat pump, on an advanced commercial absorption chiller, and on Stirling engine-driven and internal combustion (IC) engine-driven vapor compression heat pumps.

Absorption Systems. Development continued on the Engineering Field Test Unit of the residential GAX cycle absorption heat pump at Phillips Engineering Co. A basic generator-absorber configuration has been established that

ALTERNATIVE FLUOROCARBONS ENVIRONMENTAL ACCEPTABILITY STUDY

A cooperative research and development agreement (CRADA) was completed in 1992 with the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS, a chemical manufacturer's consortium) to assess the global warming impact of CFC alternatives.⁴ The concept of total equivalent warming impact (TEWI) developed during this study has been well received and is extensively cited in recent technical literature and in United Nations Environmental Program (UNEP) Assessment Panel reports. The study found that CO₂ emissions from fossil fuels (used to generate electricity to drive refrigeration systems) and from natural gas and fuel oil (used to heat homes and businesses) contribute much more to global warming than the CFC replacements that will be used in refrigeration equipment, home appliances, and building insulation. Over 98% of the total impact from refrigerator/freezers, for instance, will be due to energy use and less than 2% from the release of HFCs and HCFCs. In this context, the best opportunities for further reductions in global warming impact are in improvements to energy efficiency. In

"high-loss" applications, such as supermarket refrigeration and automobile air conditioning, opportunities exist to further reduce TEWI through new technologies and innovation because of the continued high emissions of refrigerants in these kinds of equipment. A summary of the project report is included in the UNEP Technical Options report on refrigeration uses of CFCs. The project results have played a key role in UNEP deliberations on future CFC and HCFC controls policy. A follow-on CRADA with AFEAS will provide an evaluation of the environmental impact from these next-generation, high-efficiency, chlorine-free technologies.

In addition, a project has been initiated with the Institute of Energy Problems of Chemical Physics (INEPCP) of the former Soviet Union. Under this project, INEPCP will measure atmospheric lifetimes of compounds under consideration as alternatives to HCFC-22 or HCFC-123. These measurements will be invaluable in evaluating the potential environmental impacts of these new refrigerants before they are mass-produced. ♦

solves some previous fabrication problems, now delivers thermal performance very close to project goals, and is judged to be ready for HVAC manufacturer evaluation. Full achievement of performance goals will now be a matter of balancing flows and "fine tuning" the thermal design. Fig. 5.1 shows a Phillips GAX unit on field test. Phillips Engineering is negotiating a license agreement with several potential manufacturing partner organizations. The American Gas Cooling Center, an affiliate of the American Gas Association, has organized a consortium of gas utilities to provide financial support for advanced product development.

ORNL has decided, considering the potential benefits of the GAX heat pump and the growing worldwide interest in GAX cycle development, that a parallel GAX technology effort is justified. Accordingly, a subcontract was awarded to Battelle Memorial Institute for advanced GAX absorber development. This project will be part of an informal cooperation with GRI on GAX absorption system development.

Within ERRS, work continued on advanced ammonia-water-salt fluid systems for GAX absorption heat pumps. Optimum proportions for a promising quaternary mixture were determined in electrochemical corrosion screening

tests with several conventional engineering materials. Corrosivity of the quaternary mixture appears no worse than that of the binary ammonia-water mixture. At the close of this report period, coupon stress corrosion cracking tests had been completed, results were being evaluated, and an absorber test loop was being readied for minisorber tests of the heat and mass transfer characteristics of the new fluid.

At Battelle Memorial Institute, work continued on the development of absorbent solution chemistry for the direct coupled condenser (DCC) triple effect absorption chiller cycle. A patent application for the DCC cycle was submitted to the U.S. Patent Office this year (Fig. 5.2 shows a block diagram of the DCC cycle). Battelle has identified a specialty duplex stainless steel alloy that in electrochemical screening tests appears to be useable in lithium bromide-water solutions at 450°F. In stress corrosion cracking coupon testing, a silicate inhibitor gave highly promising results, indicating that 316L stainless (a low-alloy steel) and possibly even mild steel may also be useful in certain components of the system. Subcontractor York International is evaluating manufacturability and economic feasibility of candidate materials.

Stirling Engine-Driven Heat Pumps. Sunpower, Inc., fabricated and performed preliminary testing of the first magnetically coupled free-piston Stirling engine/compressor.¹ The magnetic coupling is a low-cost alternative to the hydraulic system tested successfully in a previous hardware development program. The low-cost coupling/transmission system, together with the proven high efficiency of the Stirling heat pump, could soon lead to a competitively priced Stirling engine-driven heat pump system for residential use.

Mechanical Technology, Inc., fabricated and tested a low-cost combustor for the Stirling engine. The combustor was another high-cost

Fig. 5.1. Phillips Engineering generator-absorber heat exchange absorption heat pump on field test in St. Joseph, Michigan.

item. The low-cost alternative further increases the likelihood of a competitive, Stirling-based product.

A new approach to the design of an external heat system (EHS) for Stirling engine heat pumps involved Advanced Mechanical Technology, Inc., viewing the system from a natural gas-fired appliance perspective. To develop a design acceptable to gas industry requirements, American National Standards Institute code considerations were incorporated into the design process and material selections. A parametric engineering design and cost model was developed to perform the analysis, which included the impact of design on nitrogen oxide emission. Analysis results and recommended EHS design and material choices are given in the published study.²

IC Engine-Driven Heat Pumps. In a cooperative effort between ORNL and Tectonics Research, Inc., researchers have gained a comprehensive understanding of the dynamics of the bellows-type refrigerant seal for the linear free-piston IC engine-compressor. The high har-

monic content of the piston motion of the free-piston engine imposes constraints on the allowable seal stroke that are now well understood. Tectonics has been running a demonstration unit heat pump (Fig. 5.3) at its facility that has now accumulated 300 hours of operation. Emissions testing and fuel-system development of the Tectonics engine-compressor is in progress at Southwest Research Institute.

5.2.2 Novel Cycles

Continuing its investigation of novel refrigeration cycles, ERRS initiated gas-cycle refrigerator activities to develop non-CFC, high-efficiency refrigerators. Two companies were selected for this work under a competitive request for proposal (RFP)—General Electric and Stirling Technology Corporation. These concurrent projects will investigate the most promising systems design options, as well as critical components, performance, cost, and developmental risks. Computer simulation studies to date have shown that the coefficients of performance (COPs) of the gas-cycle refrigerators could be higher than in conventional refrigerators.

5.2.3 Refrigeration Systems

ORNL's research into CFC alternatives continued to grow last year. In the area of alternatives to R-12, work on a major CRADA with the Appliance Research Consortium (ARC, a subsidiary of the Association of Home Appliance Manufacturers) on advanced refrigerator/freezers (RFs) was initiated. The program's goal is to develop advanced technology for future RFs that will reduce energy consumption by more than

Fig. 5.2. Block diagram of the double condenser coupled-cycle absorption chiller. Only the third generator is gas-fired. The first and second generators are motivated by internal heat exchanges.

50% compared with today's products (Fig. 5.4). This year, analytical screening of refrigerant and cycle options has begun that uses data contributed from ARC members as a basis for comparison. Over 50 refrigerant blends (near azeotropes and nonazeotropes) are being investigated in both single- and two-evaporator RF cycles. Two typical RFs were contributed by a manufacturer to serve as test beds for experimental evaluation of leading options identified by the analyses. Base-line tests of these RFs are nearing completion (Fig. 5.5). ARC members and RF compressor manufacturers have agreed to provide advanced components for the test phases. Advanced concept testing will begin next year with investigation of R-134a in a single-evaporator cycle using high-efficiency compressors, fans, and low-load cabinets.

An analytical screening of "near-drop-in" alternatives to R-502 for low-temperature supermarket refrigeration was completed.³ The analysis identified several nonflammable chlorine-free mixtures that exhibited efficiency, capacity, and pressure ratio characteristics similar to R-502 (Table 5.1).

ORNL-Photo 1598-93

Fig. 5.3. Demonstration unit of the Braun linear free-piston internal combustion engine-driven heat pump in service at Tectonics Research, Inc.

In addition, researchers completed an initial analytical screening of "near-drop-in" alternatives to the HCFC R-22 for heat pump/air-conditioner applications. Over 50,000 ternary mixtures of 22 chlorine-free compounds were analyzed in the course of this work (Table 5.2). Approximately 400 nonflammable blends with COP and capacity nearly equal to or better than that of R-22 and temperature glides of under -12°C (10°F) have been identified. Detailed thermodynamic cycle analyses of these blends at heat pump rating point conditions are planned for next year. Verification testing of the top blends emerging from this analysis (along with candidate R-502 replacements) in a small refrigeration

cycle test loop is also planned for next year.

Two activities involving the DOE/ORNL Heat Pump Design Model (HPDM) were initiated this year. The variable-speed version of the HPDM was delivered to Lawrence Berkeley National Laboratory and the Air-Conditioning and Refrigeration Institute (ARI) for use in an engineering analysis of the efficiency potential of air-conditioners and heat pumps. The results of this analysis will serve as the basis for future minimum seasonal energy-efficiency ratio (SEER) standards. A new CRADA was initiated with DuPont in September for joint development of a simulation model that predicts air-to-air heat pump performance with selected alternative refrigerant mixtures ["near-drop-in" blends as well as nonazeotropic refrigerant mixtures (NARMs)] in specific system hardware. This model will be based on the existing HPDM.

Research continued on improving heat-exchanger (HX) thermal performance with NARMs. A novel, segmented-evaporator HX was installed on a laboratory test rig. The first section of this HX is designed to improve nucleate boiling of the low-quality (high liquid fraction) entering refrigerant; the second section is designed to augment evaporation in the high-quality region. Tests with R-22 and two NARMs (R-143a/R-124 and R-32/R-124) in the large-scale breadboard loop (Fig. 5.6) showed that augmented HXs are necessary for NARMs to realize their efficiency improvement potential in refrigeration systems. As Fig. 5.7 shows, system per-

Fig. 5.4. History and program goals of research on advanced refrigerator/freezer energy consumption.

formance with the best NARM (R-32/R-124) was about 20% higher than with R-22.⁵ A new program was initiated on basic heat transfer in collaboration with the HVAC and refrigeration industry through ARI. A sensitivity study was initiated to determine the impact of HX augmentation and area on HVAC and refrigeration system performance. ARI members provided base-line data for the study on a number of applications, including heat pumps, chillers, and refrigerators. Preliminary results revealed that the heat pump application could reap potentially significant benefits through use of NARMs.⁶ Figure 5.8 illustrates the impact of increasing HX size and improved heat transfer coefficient on ideal heat pump cycle efficiency. These results were reviewed with members of a Heat Transfer Advisory Panel established by ARI.

5.2.4 Work for Others for the BER Program

5.2.4.1 Advanced Surfaces for Vertical-Tube Absorbers

A GRI-funded project was completed this year with an objective to develop a practical, simple, yet broadly applicable technique to design vertical-tube lithium bromide/water falling-film-type absorbers with enhanced tube-surface

Fig. 5.5. Randy Linkous of the Building Equipment Research Program completes base-line tests of advanced refrigerator/freezers.

Table 5.1. Detailed results for the most promising chlorine-free blends for R-502 replacement

Composition			Azeotropic ΔT	ODP	GWP	Normalized ^a		
First component	Second component	Third component				COP	Pressure ratio	Volumetric capacity
14.6% R-32	85.4% R-125	0.0% R-143a	0.2-0.7° F (0.1-0.4°C)	0	740	0.98	0.95	1.25
13.2% R-32	76.8% R-125	10.0% R-134a	1.7-2.8°F (0.9-1.6°C)	0	710	0.99	1.00	1.10
13.4% R-32	80.0% R-125	6.6% R-134	2.1-3.7°F (1.2-2.1°C)	0	720	0.98	1.00	1.10
8.3% R-32	80.0% R-125	11.7% R-152a	3.2-5.9°F (1.8-3.3°C)	0	700	0.99	1.04	1.00

ΔT = change in temperature; ODP = ozone-depleting potential; GWP = global warming potential; COP = coefficient of performance.

^aR-502 = 1.00.

Table 5.2. Chlorine-free refrigerants included in the R-22 alternatives screening

Below R-22 boiling point		Above R-22 boiling point		
R-32	R-218	E-134	E-227ca	R-236ca
R-143a	CE-216	R-134	R-236cb	R-236ea
R-125	R-134a	R-245cb	R-236fa	
R-290	R-152a	R-227ca	R-254cb	
E-125	E-143a	R-227ea	CE-225ea	

geometries. Experiments were completed in a glass-walled test section with seven tube types that included spine-fin, spiral-fluted, and grooved geometries. One of the spine-fin tubes was the best performer, having a capacity almost three times that of a plain tube. The grooved tube was also an excellent performer. The project successfully demonstrated a nonintrusive laser-induced phosphorescence method of measuring solution film temperature profiles along the length of the tube. Figure 5.9 shows some of the optical instrumentations that are focused on a tiny laser-excited spot on the film surface. The final report included a series of design charts generated by Penn State University under subcontract. GRI is extending this project for a similar investigation on horizontal tubes.

5.2.4.2 EPRI Transport Property Impacts on Performance of R-22 Alternatives

A project with EPRI was initiated late in the year to extend the scope of the R-22 alternatives screening analyses. This project will examine the effect of real HX parameters and refrigerant transport properties on the projected performance of the leading "near-drop-in" R-22 alternatives emerging from the ongoing DOE-sponsored screening study described in Sect. 5.2.3 (see Table 5.1).

5.3 THERMAL AND ENVIRONMENTAL CONTROL SYSTEMS

Research in the Thermal and Environmental Control Systems Program centered on emerging energy-efficient thermal and environmental technologies for applications in conservation and renewables end-use sectors. Project activities include magnetic heat pump analysis and experimentation, zeotropic working fluid technology, and mobile air-conditioning modeling and testing. A major contribution was the new CFC/HFC Ratiometer. This novel device was selected for an R&D 100 Award (see highlight, "CFC/HFC Ratiometer").

The magnetic heat pump analysis and property characterizations were extended to several materials, including gadolinium gallium garnet. Analysis showed that substantial improvements in cooling-capacity/temperature-lift combinations can be achieved using regenerative cycles within specified field limits. Also completed were design and fabrica-

ORNL-Photo 2027-93

Fig. 5.6. Ed Vineyard performs tests with R-22 and other nonazeotropic refrigerant mixtures in the large-scale breadboard loop.

tion of a superconducting pulse magnet for implementing magnetic heat pump cycle experiments. Preliminary steady-state, transient, and loss tests were conducted. In addition, a cooperative project, partially funded by ORNL's Superconducting Technology Program for Electric Energy Systems, was initiated with Astronautics Corporation of America and ORNL Energy and Fusion Energy divisions as partners in the development of a magnetic hybrid refrigerator for high-temperature superconducting device applications. During this first year of cooperative effort, analytical, experimental, and design tasks were undertaken. Good agreement was found between the experimental results and the performance model; with the best available information, a preliminary design for the magnetic stage of the hybrid refrigerator was developed.⁸

The zeotropic working fluid technology activities include a binary mixture condensing heat-transfer test and development of the CFC/HFC Ratiometer. An existing heat-transfer test apparatus was renovated and modified for use in the experimental investigation of condensation phenomena of ammonia/water mixtures on the outside of heat-transfer surfaces. Shakedown tests were conducted with pure ammonia followed by binary ammonia/water mixtures. Data from the shakedown tests agreed well with predictions by the McAdams correlation, and preliminary data from the ammonia/water tests

Fig. 5.7. COP vs capacity: comparison of various nonazeotropic refrigerant mixtures and R-22 COPs with enhanced and smooth evaporators.

showed the expected effect of binary mixture on condensing heat transfer.

Because automobile manufacturers are focusing on R-134a mobile air-conditioning systems for the foreseeable future, program researchers initiated both analytical and experimental activities in this area. The ORNL heat pump model was modified to simulate mobile air conditioners, and an R-134a mobile air-conditioner test rig was fabricated to work under various simulated vehicle operating conditions (Fig. 5.10). The purpose of the experiment is to develop a technology data base and to validate performance improvement innovations conceived by ORNL staff members, such as reliable short-tube expanders and energy-efficient liquid over-feed heat exchangers.

Fig. 5.8. Refrigerant-side augmentation potential for pure refrigerants and ideal mixtures in air-to-air heat pumps.

Magnetic Heat Pumps

During FY 1992, Magnetothermodynamic property characterizations were selected, adapted, and compared to material property data for gadolinium gallium garnet in the temperature range 4–40 K and magnetic field range 0–6 T. The most appropriate formulations were

ORNL-Photo 6367-92

Fig. 5.9. A laser-induced phosphorescence method was successfully used to measure solution film temperatures in a vertical-tube lithium bromide/water absorber.

incorporated into a model that used methods similar to those previously developed for other materials and temperature ranges to make limitation and relative performance assessments of Carnot, ideal regenerative, and pseudo-constant field regenerative cycles. Analysis showed that, although Carnot cycle limitations on available temperature lift for gadolinium gallium garnet are not as severe as for previously examined materials, substantial improvements in cooling-capacity/temperature-lift combinations can be achieved using regenerative cycles within specified field limits if significant loss mechanisms are mitigated.

Researchers completed design and fabrication of the superconducting pulse magnet for implementing magnetic heat pump cycle experiments. Preliminary steady-state, transient, and loss tests were initiated. Although recent material development efforts have raised superconducting critical temperatures substantially, practical applications most likely will require cooling in the cryogenic temperature range for the foreseeable future. Magnetic refrigeration offers the opportunity for improved efficiency and reliability in cryogenic cooling applications if performance estimates can be achieved in practice. A key requirement for any practical magnetic

refrigeration system is the realization of relatively high magnetic fields with relatively low losses, essentially the exclusive realm of superconducting magnets. In other words, magnetic refrigeration is a rare combination—both an application of, and an enabling technology for, superconductors.

In recognition of this opportunity, a cooperative project, partially funded by ORNL's Superconducting Technology Program for Electric Energy Systems, was initiated with Astronautics Corporation of America and ORNL's Energy and Fusion Energy divisions as partners in developing a magnetic hybrid refrigerator for high-temperature superconducting device applications. Analytical, experimental, and design tasks were undertaken during this first year of work. After facility modifications, tests with both the primary magnetocaloric material and alternatives were conducted in the Active Magnetic Regenerator Universal Test Apparatus. The primary material can span the temperature range of 25 K to 80 K with no refrigeration load and 40 K to 80 K with a refrigeration load operating in an active magnetic regenerator cycle. Good agreement was found between the experimental results and the performance model.

Using preliminary cycle performance analysis, researchers developed a conceptual design. With the magnet size, shape, field, and protection requirements from the conceptual design,

ORNL-Photo 7444-92

Fig. 5.10. David Kyle conducts tests on the mobile air-conditioning test rig.

CFC/HFC RATIOMETER

Research in refrigerant mixtures has been actively pursued in recent years for energy efficiency and environmental protection. However, no simple instrument was available for measuring mixture composition. This past year, an in-house innovation in zeotropic working fluid technology was the development of the CFC/HFC Ratiometer, an instrument that can quickly and easily determine the composition of a refrigerant mixture. The device is based on the principle of charged particle drift in an electrical field. ORNL researchers discovered that the charged particle drift velocity of a refrigerant mixture is linearly proportional to the zeotropic mixture composition (Fig. 5.11). This led to the inven-

tion of the CFC/HFC Ratiometer (Fig. 5.12), which won an R&D 100 Award in FY 1992. ♦

Fig. 5.11. Calibration curve for R-134a and R-12 mixtures.

ORNL-Photo 4904-92

Fig. 5.12. Breadboard setup of the CFC/HFC Ratiometer.

magnet design analysis was performed to characterize winding specifications, flux return options, force predictions, and heat-leak/dewar implications for a magnet system employing available low-temperature superconductors. Based on the heat rejection requirements of the

magnetic (low-temperature) stage, surveys were conducted of available and developmental refrigeration systems for applicability to the high-temperature stage of the hybrid machine. Realistic high-temperature stage options and trade-offs were summarized, and low-tempera-

ture/high-temperature stage interface requirements were established. With the best available information, researchers developed a preliminary design for the magnetic stage.

5.4 BUILDING THERMAL ENVELOPE SYSTEMS AND MATERIALS

The envelope of a building—its roof, walls, and foundation—is a key determinant in fixing the building's energy requirements. Building envelope research at ORNL is performed by the Building Thermal Envelope Systems and Materials (BTESM) Program, which receives most of its funding from the Building Systems and Materials Division of the Office of Building Energy Research of DOE. The research covers walls, foundations, roofs, attics, and building materials. The BTESM Program identifies energy savings opportunities in envelope systems and addresses them in research projects conducted jointly with industry.

As a National User Facility, the Building Envelope Research Center (BERC) is used by industry, manufacturers, professional associations, and other interested groups on an "as available" basis. Although the focus of BERC efforts is nonproprietary testing with dissemination of results, some proprietary research is also conducted. BERC is jointly funded by its users and DOE. Its purpose is to investigate the thermal efficiency and physical durability of roof waterproofing materials and insulations; innovative wall systems; the structural stability of system designs; materials compatibility; and measurement procedures and guidelines for materials selection, design, and installation. By sharing the results of these studies with industry, DOE encourages the development of improved envelope materials and designs.

5.4.1 Non-CFC Polyisocyanurate Insulation Testing

Field testing of non-CFC polyisocyanurate (PIR) roof insulation systems has been conducted for 1300 days on the Roof Thermal

Research Apparatus (RTRA). This completes the original 3-year CRADA involving the Polyisocyanurate Insulation Manufacturers Association, the Society of the Plastics Industry, the National Roofing Contractors Association (NRCA), DOE, and the U.S. Environmental Protection Agency. Data indicate that the experimental HCFC alternatives have thermal conductivity (k)-factors 3 to 9% higher than the currently used CFC-11 produced insulation boards.

Thermal performance of HCFC boards has actually remained more stable over the last year compared to CFC-11 boards. After the first year of testing, the measured thermal penalty of the HCFC alternatives was 7 to 12%. The thermal drift of both CFC and HCFC boards, after 3.4 years, has slowed considerably.

Data from the thermal performance and mechanical property measurements conducted on the Envelope Systems Research Apparatus (ESRA)—largely by Roof Research Center users from the NRCA—conclude that all HCFC alternatives have acceptable behavior as replacements for the CFC-11 blown PIR board currently used in over half of the low-sloped roofs in the United States.

The manufacturers of PIR insulation (CRADA partners) have begun to distribute PIR board stock produced with HCFC-141b, one alternative to CFC-11 tested on both the RTRA and ESRA. Thanks in part to this joint research, the PIR industry has announced it will completely phase out CFC-11 use by the end of 1994.

The overall objective of this research is to determine the long-term thermal performance differences between PIR foamed with CFC-11 and PIR foamed with HCFC-123, HCFC-141b, and two blends of HCFCs. Boards from the same batch were installed in outdoor test facilities and were instrumented to determine whether the insulation thermal performance aging characteristics are at all dependent on how the boards are handled and installed in the field. A major contribution of this research is field validation of an accelerated thermal aging procedure. Short-term laboratory measurements of the apparent k of 10-mm-thick slices are used to predict the k of 38–50-mm-thick PIR-laminated boardstock for 12–20 years after production. In situ thermal performance measurements of these well-char-

acterized 3-year-old boards under either white or black ethylene propylene diene monomer (EPDM) membranes were compared with the accelerated aging procedure and with boards from the same batch in different roofing systems: mechanically attached EPDM, fully adhered EPDM, and built-up roof (BUR). The comparison indicates that this accelerated aging procedure should be considered for providing in-service thermal performance information to building owners and roofing contractors.

The aging rate is the same whether the membrane above the insulation boards is black or white. However, direct application in a fully adhered EPDM membrane system appears to cause a 6–8% loss in R-value. The impact of asphalt encapsulation is mixed. Two of the three BUR systems tested were found to cause an immediate loss in thermal performance similar to that found in the fully adhered EPDM system. One BUR system showed no significant effect of the initial asphalt encapsulation. The accelerated aging procedure used to predict the long-term thermal performance does a good job of predicting the conductivity of loose-laid boards under the EPDM membrane on the RTRA, which are not walked on or in contact with any adhesives or asphalt.

Based on data recorded in the ESRA with these boards installed under either BUR or a fully adhered EPDM, the accelerated aging procedure in the first 5 years appears to underestimate the thermal conductivity by up to 10%. For most roof systems, the accelerated aging procedure appears to be able to predict long-term thermal performance of PIR within 5% of field performance. This work has been extended another year to include development of improved and environmentally acceptable foam insulation boards.

Attics

Large Scale Climate Simulator tests with an attic test module have demonstrated that the thermal resistance of some loose-fill fiberglass insulations can decrease by as much as a factor of two in cold climates because of air circulation between the warm ceiling below the insulation and the cold attic space above. ORNL research on convective heat loss in attic insulations by

Ken Wilkes and Phil Childs was selected as "One of the Year's 100 Greatest Achievements in Science and Technology" by *Popular Science* magazine.

The impact of this research is present in the state of Minnesota Energy Codes, which now require insulation R-values to be reported at winter design temperatures as well as at the Federal Trade Commission required mean temperature of 23.9°C (75°F). In addition, American Society for Testing and Materials (ASTM) Committee C-16 on Thermal Insulation is developing new test procedures for attic insulation that capture insulation performance under realistic conditions in the field.

R-30/30 Roofs

Research on various aspects of roof materials, design, and installation techniques is being coordinated to develop roofs that achieve a thermal resistance of R-30 with a lifetime of 30 years. Current research is centered on materials aging, thermal stresses, and moisture degradation.

The ORNL roof recover project, initiated in FY 1992, promises to involve several private industry CRADA partners. This project, led by Andre Desjarlais and David Kyle, extends the center to include several additional buildings at ORNL, one being the ORNL cafeteria. It will be recovered with a new roof, saving energy and the high cost of disposing of hazardous materials in the 40-year-old roofing materials.

5.4.2 Organizers Of International Envelopes Conference

This year a major effort focused on organizing and participating in the Fifth International Thermal Performance of the Exterior Envelopes of Buildings Conference. Jeff Christian, BTESM Program Manager, was the conference chairman, and Pat Love was conference director. More than 100 speakers presented papers at this conference.

2 of 3

5.5 EXISTING BUILDINGS RESEARCH

Research focusing on technical and implementation issues for improving the energy efficiency of existing buildings is included in two programs for DOE: the Existing Buildings Efficiency Research Program for the Office of Building Energy Research, and the Weatherization Assistance Program (WAP) for the Office of Financial and Technical Assistance. The Army Engineering and Housing Support Center and U.S. Air Force sponsored related research on energy efficiency during family housing revitalization. Also, an evaluation continued for Commonwealth Electric Company of an efficient lighting installation program in small commercial buildings.

Through the above combination of supporting organizations, the Existing Buildings Research Program operates as a national program to assist public and private agencies in improving the energy efficiency in existing residential, commercial, and industrial buildings. The overall goal of the program is to develop the tools to achieve energy savings of 3 Quads/year in residential buildings and 2 Quads/year in commercial-industrial buildings by the year 2030. To realize this goal, the program will focus on (1) technologies and procedures that can reduce energy use by 50% or more from a 1990 base line, and (2) demonstration and deployment of proven technologies in collaboration with the key stakeholders responsible for efficiency delivery programs.

5.5.1 Residential Buildings

Two field studies were performed with the state of Arizona to investigate retrofit measures designed to reduce cooling energy consumption and electric demand. A study initiated in 1991 was completed that examined the performance of an exterior insulation retrofit on walls of eight concrete block houses. Two inches of foam board insulation were attached to exterior wall surfaces, and the insulated walls were finished with stucco. Total per-house costs to perform the installations ranged from \$3610 to \$4550. The

field study was cost-shared by DOE, the Arizona Department of Commerce, Salt River Project (the local electric utility), Dow Chemical Co., and Western Stucco Products. The study concluded that exterior masonry wall insulation can reduce air-conditioning electricity consumption and peak demand in hot, dry climates and that conservation programs in this climate should consider including this retrofit measure. Average annual cooling energy savings of the eight test houses were estimated to be 491 kWh, or 9% of pre-retrofit consumption. Peak demands without and with insulation on the hottest day of an average weather year for Phoenix (shown in Fig. 5.13) were estimated to be 4.26 and 3.61 kW, for a demand reduction of 0.65 kW (15%) per house. Factors that could improve the cost effectiveness of the measure include lower-cost installation methods; utility DSM subsidies; installation in conjunction with house siding or remodeling; and improved house appearance, value, and comfort. Modeling was completed to estimate retrofit performance in other cooling climates.

A second field test in Arizona was initiated this year to determine the extent of duct leakage and air-conditioning operational problems of residential houses in the service territory of Salt River Project and the degree to which duct leaks can be repaired. Costs associated with repair work and monthly electricity consumption are also being monitored. Holes in ductwork, dis-

Fig. 5.13. Predicted air-conditioning electricity demand with and without exterior wall insulation for the hottest day of an average weather year for Phoenix, Arizona.

connected joints, and improper designs are some of the major culprits that cause air-distribution systems to increase air leakage, energy consumption, and electricity demand. Air-conditioning equipment operation problems include incorrect refrigerant charge, low air flow, and equipment placement; these problems are often overlooked or not addressed properly by repair technicians. Costs are being shared by DOE, Salt River Project, and the Arizona Department of Commerce. One hundred houses will be diagnosed for these problems, and repairs will be performed as needed. At the end of this period, planning for the field test was completed, and training of local contractors began. Data analysis and reporting of the field data will be completed next year.

Field testing is also being performed in Florida with the Florida Solar Energy Center to investigate the impact of duct-leakage repairs on air-conditioning electricity consumption. Duct repairs were performed this summer on eight houses monitored previously under a separate study. Pre-weatherization monitoring was performed on an additional eight houses this summer, with monitoring to continue next summer after duct repairs are made. The test includes monitoring the following data at 15-minute intervals: electricity consumption, indoor air temperature and relative humidity, evaporator coil temperatures, air flow through the evaporator coil, and weather. Data analysis and reporting of the field data will be completed next year.

The field test of a preliminary version of the advanced audit in North Carolina was completed. The field test involved three groups of 40 houses: (1) a group weatherized by the current North Carolina program, (2) a group weatherized as recommended by the audit, and (3) a control group that received no weatherization. Many of the improvements made to the audit this year to complete its development were recommended from use in the field test. The field test concluded that substantial space-heating energy savings were achieved by both the advanced audit and the North Carolina Program (23% and 19% of pre-weatherization space-heating energy consumption, respectively), with the advanced

audit producing slightly better results (see Fig. 5.14). The advanced audit recommended wall insulation for many houses and made few recommendations for storm windows. Average installation costs (approximately \$1050) were the same for both approaches. Small air-conditioning electricity savings were achieved under either approach. The final report for the field test will be published next year.

Modification was essentially completed for the advanced, interactive single-family energy audit for use in all regions of the United States. The format of the audit was improved and weatherization measures added. Preparation of a user's manual is almost completed, and a training session was developed and tested at two workshops for DOE Headquarters and Support Office staff. The completed personal computer-

Fig. 5.14. Distributions of space-heating energy savings by group (midpoints of ranges shown: 40 represents range from 30 to 49, etc.).

LOW-INCOME WEATHERIZATION ASSISTANCE PROGRAM

During FY 1992, the Energy Program Planning and Evaluation Group initiated five studies comprising the national evaluation of the U.S. Department of Energy's (DOE's) low-income Weatherization Assistance Program (WAP).^{9,10,11} Reports on two of the studies were published. One, *Characterization of the WAP Network*, describes weatherization practices of state and local WAP agencies, the nature of agency staff and resources, public and private partnerships, obstacles to progress, and opportunities for the future.¹² The second, *Scope of the WAP*, describes the types of low-income dwellings weatherized with DOE, utility, and other funds. The study indicates that from 1978 to 1989, \$4.4 billion was spent on full-scale weatherization activities, resulting in partial or complete weatherization of 3.9 million units.¹³ The next phase of this study will characterize the eligible population that remains to be served.

The other three studies will estimate impacts of the WAP in key submarkets, including (1) single-family and small multifamily

dwellings, (2) high-density multifamily dwellings, and (3) homes heated with fuel oil. Altogether, information is being collected from 48 states, 400 local WAP agencies, 800 utilities, and 10,000 homes. Some of the many innovations incorporated into these studies include the following:

- close involvement of stakeholder representatives in the evaluation;
- retention of homes where occupants have changed, in the savings analysis;
- split-winter design with metering to quantify energy savings in fuel-oil homes;
- application of a heating and cooling model for weather normalization;
- assessment of weatherization impacts on the health and safety of occupants; and
- estimation of indirect economic and environmental externality impacts.

The evaluation will be completed in 1993. ♦

based audit will be distributed to all states as an approved National Energy Audit for the DOE WAP, and state personnel will be trained in its use.

A draft planning guide for whole-neighborhood revitalization of Army family housing was completed for the U.S. Army Engineering and Housing Support Center, and a training curriculum was developed and tested. This military program provides a systematic approach to determine the most appropriate extent of repair and modernization needed to upgrade Army housing units and their surrounding neighborhoods. The planning guide was developed to simplify the process of identifying the scope of a revitalization project, the cost estimate, and the

preparation of forms required for project approval. ORNL provided guidance to ensure the maximum cost-effective level of energy efficiency during rehabilitation, and the National Association of Home Builders Research Center provided guidance on structural and functional considerations, architectural improvements, and health and safety issues.

A field investigation was performed for the Air Force to determine whether energy efficiency is adequately addressed in the housing community plans developed as the basis for designing a major rehabilitation project. The investigation revealed that the expected readily attained level of energy efficiency following renovation will not necessarily be achieved. Renovation work

specified in the plans generally complies with current Air Force regulations and is generally consistent with public energy standards. However, design and construction flaws can exist in the housing that adversely affect energy consumption. Examples of these flaws include problems with the air-distribution systems that allow outside or attic air to enter the return air stream and allow conditioned air to leak to the outside; leakage sites in the envelope of the units that increase the infiltration of the units; and envelope insulation missing in non-routine places such as second-story overhangs. Figure 5.15 shows some of these typical duct and return plenum problems. These housing deficiencies are not completely addressed in the current Air Force regulations or guidelines and, therefore, are not addressed in the Housing Community Plans. Additionally, some of the renovation work specified in the Housing Community Plans is not energy efficient and contributes to increased energy consumption.

A new project was initiated for the Air Force and DOE as a result of this field investigation. This project will provide the Air Force with three state-of-the-art technical guidebooks that will assist in meeting the goals of the NES to improve the efficiency of energy use in family housing. Initiatives are under way to include the other services in the project as well. The first guidebook will be written for the architectural and engineering firms developing detailed revitalization designs. It will provide information on the most current efficiency technologies and inspection methods for identifying actual problems. Detailed procedures will be presented for determining the most cost-effective measures to bring the house into compliance with military standards. The second guidebook will be an inspection guide to ensure both that inspectors understand the advanced technologies and that measures are properly installed and operated. The final guidebook will focus on an energy retrofit program for housing not scheduled for major revitalization.

These guidebooks will be developed from inspections of military family housing. All recommendations will be field verified, and actual energy consumption will be monitored to confirm energy savings. Development of the first two draft guidebooks and diagnostic inspections of housing units will be completed next year.

Fig. 5.15. The return plenum of units 5174B and 5425A was connected to the attic and/or outside by the interior walls used to form the plenum (no dry wall was installed on the plenum side of the studs, as shown in top photo), gaps around plumbing running through the plenum, and a pipe used to run refrigerant and condensate lines outside (bottom photo).

5.5.2 DOE-HUD Initiative

The section's contribution to integration of energy efficiency into U.S. Department of Housing and Urban Development (HUD) public and subsidized housing during the rehabilitation process included technical input for a video for workers who specify and inspect rehabilitation work and a performance contracting guide for public housing authorities (PHAs). The video "Eye On Energy—Rehab for all Seasons" provides general guidance to PHA managers and HUD field offices on the techniques, materials, and recommendations for air sealing, thermal insulation, and mechanical equipment retrofit for energy efficiency during rehabilitation. The performance contracting guidebook was developed to assist the larger PHAs in implementing new HUD procedures that provide incentives for major energy-efficiency investments. The new incentives recognize that energy efficiency is the only investment in public housing that can pay back and, therefore, that can be financed with third-party funds. The developed guide provides the first clear instructions for PHAs to promote national implementation of appropriate energy-efficiency projects.

5.5.3 Commercial Buildings

The ASTM standard guide on energy monitoring "protocols" for commercial and institutional buildings or facilities, approved by ASTM Committee E06 on Performance of Buildings last year, was approved by the full society this year. The standard is designated E 1464-92.

A project to develop metering guidelines for verification of energy savings from retrofit projects in (large) institutional buildings was initiated this year with Texas A&M University. The Texas LoanSTAR program is a unique effort to verify energy savings in support of a \$98 million revolving loan fund in Texas. Results from the LoanSTAR program have potential impacts for other states and the federal government for energy-reduction programs. Plans are for the guidebook to be available next year.

A field study of the energy-saving benefits of energy controls retrofits is under way in the

United Nations Building in Washington, D.C. The demonstration will measure energy savings for different control functions and indicate areas where DOE involvement in energy controls might be useful. A calibrated simulation model of the building (using the DOE-2.1D computer program) has been developed and will be used together with short-term testing data to estimate the energy savings from previous retrofits and the incremental benefits from controls functions available in the building's energy management system.

The evaluation of energy savings and cost effectiveness of a DSM program continued for small commercial buildings at Commonwealth Electric in Massachusetts. The program is initially focused on lighting retrofits. This evaluation has shown that the program appears to be marginally cost effective, but significant potential was also identified for improving cost effectiveness through better screening of installation jobs. New evaluation methods for commercial building programs are being developed and tested under this project, and researchers plan to begin publishing information on methods development and testing next year.

Study of methods and results for high-speed collection of electrical power data (up to 1 kHz sampling) in commercial buildings continued this year, with testing of prototype hardware and examination of initial data results. Figure 5.16 provides an example of the type of information that can be obtained. Further study of energy

Fig. 5.16. Data showing equipment starts and stops collected at the electrical service entrance to Building 3147.

use and potential energy savings reflected in this type of data will continue next year.

The state of Florida is working to reduce energy consumption in state buildings by 30% over the next few years. The Existing Buildings Research Program has agreed to provide technical support to Florida in coordinating and conducting research studies on the use of energy-efficiency technologies in state buildings. As part of this coordinated effort, transfer of methods from the Texas LoanSTAR program will be pursued. Documentation of energy savings from performance contracting projects is also planned.

5.6 ENERGY PROGRAM PLANNING AND EVALUATION

The major research focus of the Energy Program Planning and Evaluation (EPPE) Group continues to be quantitative assessments of energy-efficiency programs operated by utilities and government agencies. During FY 1992, the group continued assessment of the commercial impacts of DOE's Energy-Related Inventions Program (ERIP), evaluated a residential weatherization program operated by the Bonneville Power Administration (BPA), initiated a comprehensive evaluation of DOE's low-income WAP, and undertook an assessment of two information services programs operated by DOE: the National Appropriate Technology Assistance Service (NATAS), and the Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS).

Since 1984, ORNL has tracked the progress of inventors whose technologies have been ERIP-supported. The goal has been to assess program impacts on the commercialization of new energy technologies. During FY 1992, the group continued to compile information on the progress of ERIP inventions.^{14,15} Multiple pro-

gress indicators included (1) the commercialization rate of ERIP-supported technologies, (2) the time required to move a technology from the laboratory to the marketplace, (3) the number of years ERIP technologies experienced sales, (4) the number of jobs generated, and (5) the amount of funding raised. Comparing these indicators to private-sector, new-product development statistics suggests that ERIP has been effective. ERIP-supported technologies have generated more than a half-billion dollars in sales; through 1990, 23 spin-off applications generated sales of \$32 million, representing additional benefits to the ERIP investment (Fig. 5.17).

Over the past decade, the group has completed a series of evaluations of BPA's residential weatherization programs, which have examined the energy saved by participants and assessed the durability of savings up to 3 years after weatherization. During FY 1992, evaluations of the 1988 and 1989 programs were completed.¹⁶ Altogether, these studies constitute an unprecedented analysis of the persistence and durability of energy savings from residential weatherization; energy savings decreased by 10–20% each of the first 3 years after weatherization. For both the 1988 and 1989 programs, actual savings during the first post-weatherization year fell far short of the audit-estimated savings—42% and 31%, respectively. These results are consistent with prior evaluations conducted for BPA and

Fig. 5.17. Cumulative sales of Energy-Related Inventions Program (ERIP) inventions and spin-off technologies.

HIGH-ALTITUDE ELECTROMAGNETIC PULSES

A 10-year research effort was successfully completed during FY 1992 to assess the impacts of high-altitude electromagnetic pulse (HEMP) on electric power systems.²²

The scope of the project included a review of existing HEMP coupling and interaction models and the development of new models pertinent to the power system analysis. Laboratory and field experiments were performed to characterize the behavior of power system components and subsystems subjected to fast-rising HEMP-induced surges. A methodology was developed for combining the analytical results with the measured component responses to permit an assessment of power system behavior when subjected to HEMP. The methodology was used to model a subset of the U.S. power system to validate the assessment. The probable behavior of the power system when exposed to HEMP was then determined based on the assessment methodology.

A nuclear detonation in or above the earth's atmosphere produces an intense electromagnetic pulse that will interact with electric power lines. Electromagnetic fields radiated from the blast vary greatly with weapon characteristics, yield, and detonation height. Electromagnetic disturbance is divided into three components, denoted by E₁, E₂, and E₃, depending on the production mechanism and the observed time of the disturbance.

The early-time component of HEMP, E₁, is a steep-front, short-duration pulse with a rise time of a few nanoseconds and a decay time less than 1 microsecond. A single high-altitude nuclear burst at a height of about

400 km (249 miles) can subject much of the continental United States to an E₁ HEMP electric field with a peak amplitude on the order of tens of kV/m. The intermediate-time HEMP, E₂, is a more slowly varying and less intense electromagnetic field with an electric field strength of several hundreds of V/m and a typical duration time of several hundred microseconds. The late-time HEMP, E₃, is a very low amplitude pulse on the order of tens of V/km. The E₃ HEMP response, resulting from geomagnetic perturbations caused by the high-altitude nuclear detonation, has a response time up to several hundreds of seconds. The E₃ component of the HEMP signal, often referred to as magnetohydrodynamic EMP, may affect power systems similarly to geomagnetic storms.

The early-time component, E₁, and the late-time component, E₃, of HEMP were found to affect electric power systems. When both are considered, research indicates that a major power system disturbance due to the HEMP produced by a single high-altitude burst over the continental United States cannot be ruled out. Such an event could cause the interconnected electric power networks in the country to break up into utility islands, resulting in massive power failure in some areas. However, permanent damage would probably be isolated, and restoration of the electrical power service should be possible within a few hours. If multiple high-altitude bursts were to occur, the size of the blackout areas could increase, along with an increase in component failures and system restoration time. ♦

others (see highlight, "Low-Income Weatherization Assistance Program").

The assessment of NATAS and CAREIRS, initiated in FY 1992, indicates that (1) clients appear to be using information and technical assistance in diverse settings; (2) intake and response procedures can be improved to better address client needs; (3) typical CAREIRS and NATAS clients have more than average incomes, with high levels of formal education; and (4) clients are satisfied with the information services. Future work will focus on information service life cycles and process and product quality as they relate to productivity.

5.7 INTEGRATED RESOURCE PLANNING

In 1992, ORNL assisted DOE in developing an Integrated Resource Planning (IRP) Strategic Plan (July 1992). This plan describes a process for using IRP to support the objectives of the NES.

Other ORNL activities this year also built upon earlier projects. A handbook was developed to encourage common terminology and assist practitioners in evaluating DSM.¹⁷ Studies of the relative effects of DSM on prices and costs for utility services,¹⁸ the effects of utility DSM programs on risk,¹⁹ and the role of collaboratives in designing DSM programs²⁰ were completed. The program also initiated new projects:

- It commenced development of an "expert system" with EPRI by which practitioners might select the kind of DSM evaluation best suited to particular requirements. This expert system is being developed with EPRI to ensure its immediate usefulness within the utility industry.
- It began an analysis of the effect active DSM could exert on the price of emission credits under the Clean Air Act Amendments of 1990.
- It began a study of the role of electricity pricing in the integrated resource stack, a study that will evaluate the cost and performance of pricing (with its demand

elasticity) vis a vis demand- and supply-side alternatives in meeting service requirements.

- It initiated six new IRP-related projects, awarded as the result of a DOE RFP managed by ORNL in areas of considerable concern to practitioners around the country. The studies are being done in partnership with various utilities around the country, so the results will have practical application to those utilities as well as advance the state of IRP and DSM nationally. Reports are to be generated by each project, and a workshop is being considered that will further amplify the results.

Utilities are currently spending nearly \$2 billion per year on DSM programs. (Expenditures and programs must be reported to the government on EIA Form 861.) An analysis of the first round of reporting (1990 data) was completed by ORNL in 1992.²¹ This analysis showed that the resources devoted to DSM varied markedly across companies, with some companies much more committed to DSM than others. It also revealed that tightening definitions is necessary to ensure comparability of data in the future. This and previously cited work is important in assisting the evaluation of the DSM resource, one of the clear priorities for IRP in the future. Questions are increasingly being raised about how much efficiency is actually being achieved by utilities, how permanent these savings are, and how much this "resource" is costing. In several interrelated ERRS programs, these questions are being addressed by field research. The research will be important both in the individual settings in which the results are derived and, in aggregate, to DOE's NES goals and adjustments.

ORNL staff members continue to make numerous presentations at various conferences, seminars, and workshops in the United States and abroad. Interest in IRP is increasing in developing countries and the newly independent states of Eastern Europe and the former Soviet Union. ORNL is attempting to be responsive to these broader claims and integrate its IRP activities within broader economic, environmental, and energy agendas of nations in the

midst of dramatic change to market-based economies.

Finally, IRP is being integrated more closely with other ongoing activities within and outside the division. It is being integrated under the rubric of an integrated *utility* perspective that, for example, searches for synergies between power system technology (T&D) developments and IRP. Work for new sponsors, including the Domestic and International Energy Policy Group within DOE, is revealing a path for closer utility-based integration of IRP activities into related activities in which ORNL is actively participating.

5.8 TECHNOLOGY TRANSFER FOR BUILDINGS

The mission of the Technology Transfer for Buildings Program is to implement a system for efficient and effective transfer of R&D results to private and public sector users and to facilitate the exchange of information among energy service providers.

During FY 1992, the program initiated a widely disseminated newsletter that documents ongoing technology transfer activities across the DOE national laboratory system. The program also organizes a series of buildings-oriented information meetings for the ten DOE Regional Support Offices. These semi-annual meetings move from region to region and include business

sessions, technical presentations, and tours of nearby buildings research facilities.

In June 1992, the program provided organizational support for a workshop in Atlanta on Building Energy Efficiency in the Southeastern United States. The workshop was attended by many energy service providers, state and local energy officers, and utility personnel. The workshop provided a forum for discussion of issues specific to the Southeast and identified issues unique to the region. A summary of the workshop will be provided to attendees, and a follow-up is tentatively planned for June 1993.

5.9 COMMUNITY ENERGY SYSTEMS

ORNL serves as lead laboratory, providing technical and management support to the DOE Office of Utility Technologies, Utility Systems Division, for the District Heating, Cooling, and Cogeneration (DHC/C) Program. The mission of this program is to develop and promote the application of cost-effective DHC/C technologies for the benefit of national energy and economic efficiency, energy security, and environmental quality.

Following a successful DHC/C workshop held in October 1991, a National Action Plan for DHC/C was generated. A major effort currently under way is to supplement and monitor the results of this DHC/C National Action Plan.

Also, one of the most important action items defined in the National Action Plan is to accurately characterize the DHC/C community in the United States to provide base-line intelligence for decision making. Thus far, over 500 DHC/C systems in the United States have been reported, providing vital data that will facilitate characterization of the DHC/C community.

Other program highlights include research in conjunction with Ohio State University to reduce the pumping energy losses in DHC systems; issuance of grants to two universities and one municipality to apply innovative cogeneration applications to existing DHC systems; and evalu-

Randy Linkous visits the Appliance Environmental Chamber.

ation of HEATMAP, a graphical analysis and personal computer-based software program used to assess the feasibility of, and perform pre-design studies of, DHC/C systems.

5.10 POWER SYSTEMS TECHNOLOGY

The objectives of the Power Systems Technology Program are to improve the capacity, flexibility, and efficiency of the nation's electric T&D systems while maintaining a high level of system reliability and safety. The program is being conducted in a coordinated effort with the DOE Power Marketing Administrations, EPRI, and other parties interested in electric utility R&D. Program activities are directed toward developing techniques and methods for the real-time control and operation of the power system, technologies with increased power capabilities for the country's electric power delivery system, integration of renewable generating technologies into the T&D system, and investigation of the biological effects of electromagnetic fields produced by electric power lines. R&D management responsibilities include the Transmission and Distribution Technologies and Electromagnetic Field Effects programs funded by the DOE Office of Energy Management.

5.10.1 Real-Time Control and Operation of Electric Power Systems

The ability to more precisely control and operate a power system in real-time will improve its capacity and flexibility. Real-time control and operation will allow the nation's T&D system to operate closer to capacity limits by developing the next generation of control center hardware and analytical methods, communications, monitoring, and control technologies.

The key to real-time control is the ability to monitor essential parameters on the power system in real time, locally process and communicate this information to control points, analyze the data using sophisticated computers and network models, decide upon a control strategy or action, and transfer this decision to remotely controlled devices in a short enough time period

to be effective. Real-time control for electric power delivery systems will be necessary for the nation's electric power systems to integrate new technologies, relieve increasingly loaded transmission lines, take advantage of renewable resource generators and energy storage, make improvements in operating efficiency, deal with the increasing number of power transfers between electric utility systems, and improve economic and environmental dispatch.

To identify R&D opportunities for real-time control and operation, a workshop with industry was held on November 19–21, 1991, in Denver, Colorado. The workshop was sponsored by ORNL, BPA, and Western Area Power Administration (WAPA). A total of 76 power-system experts attended, representing utility companies, manufacturers, and universities. Fourteen technical papers were presented on advanced monitoring and control techniques, and four planning sessions were conducted.

Workshop participants defined six broad areas of R&D opportunities: (1) optimal transmission system operation, (2) optimal distribution system operation, (3) advanced power-system technologies, (4) on-line sensing systems, (5) local control, and (6) power-system engineering research needs.

5.10.2 High-Capacity Transmission and Distribution Options

Meeting the nation's expected need to transmit large amounts of electric power will require improvements in the capacity of today's electrical T&D network. U.S. electricity consumption is projected to rise faster than any other end-use fuel and will double over the next 40 years, reflecting the increasing electrification of the U.S. economy. Incremental improvements in transmission, such as optimized conductor and line design and dynamic conductor rating, can be made but will not be sufficient. The development of advanced technologies, such as high-voltage dc (HVDC), high phase order, flexible alternating current (ac) transmission, and ultra-high voltages will be needed to provide necessary network capacity.

HVDC transmission has the potential to meet the needed transmission capacity in the

early 21st century by converting and upgrading existing ac transmission lines or by building new lines when new rights-of-way are available. To improve the economic feasibility of HVDC, the dc converter station costs need to be reduced by an estimated 40 to 50%. The converter station contains the equipment required to convert ac to dc at high voltages; the cost of these components is shown in Fig. 5.18. Such a cost reduction could make dc transmission competitive with ac transmission for line lengths in the 150- to 500-mile range.

To identify R&D opportunities for HVDC technology, a workshop on HVDC transmission technology was held with industry on May 6-8, 1992 in Portland, Oregon. The workshop was sponsored by ORNL, BPA, and WAPA. A total of 78 dc experts attended, representing 11 foreign countries. Eighteen utility companies sent 35 representatives. The world's four leading dc manufacturers had 18 experts lead a 2-hour panel session on dc technology.

Specific areas of HVDC research identified in the workshop are the development of (1) advanced semiconductor switching devices, (2) reduced component converter circuit designs, (3) advanced converter transformer designs, (4) active and statistical filtering of harmonic interference, (5) electrical grounding techniques using current flows deep within the earth, and (6) better analytical capability of existing and new HVDC applications using improved and standardized electrical models.

ORNL continues to technically monitor the progress of the DOE high-phase-order demonstration project. This demonstration is being conducted by New York State Electric & Gas Corporation (NYSE&G) in Binghamton, New York. As shown in Fig. 5.19, an existing 1.5-mile double-circuit 3-phase line operating at 115-kV line-to-line has been converted to 6-phase operating at 161-kV line-to-line. A 73% increase in line capacity is technically possible when converting from 3-phase to 6-phase operation. The detailed line design and construction were completed between May 1990 and July 1992. During the first week of July 1992, the 6-phase line was energized and placed into operation for 2 years of testing.

The \$11.4 million demonstration is being funded by an industry consortium consisting of NYSE&G, Empire State Electric Energy Research Corporation (ESEERCO), New York State Energy Research and Development Authority, New York State Energy Office, EPRI, and DOE. On August 14, 1992, a dedication ceremony celebrated the world's first commercially operated 6-phase transmission line.

5.10.3 Power Transients

Power transient studies have focused on the effects of geomagnetic-induced currents caused by solar magnetic storms on electric power systems.²³ A geomagnetic disturbance monitor is being installed at ORNL to monitor the earth's magnetic field and electric field associated with a disturbance of the geomagnetic field during solar storms. This data will be used along with data from the National Oceanic and Atmospheric Administration and EPRI sites to characterize severe solar storms across the country. This information will be used to develop a better understanding of solar storm interaction with electric power systems (also see highlight, "High-Altitude Electromagnetic Pulses").

5.10.4 Renewable Energy Technology

Renewable generating technologies like photovoltaics and wind turbines are a potential source of central and dispersed generation for electric power production. Two Congressionally requested studies were initiated in FY 1992 to examine the costs and benefits of renewable generation to the power system. The first study will examine the impact of connecting renewable generation on the distribution system to

Fig. 5.18. Cost breakdown for a typical high-voltage dc station.

reduce the requirements of central generation and transmission with their associated costs and energy losses. The study will also examine the more complicated design and operation of the distribution system created by the condition of bi-directional power flow on circuits designed for one-way power flow. The second study will examine the transmission requirements to deliver energy from large renewable generation projects located at a distance from electric load centers. These studies should be completed in FY 1993.

5.10.5 Materials

Study continues of the production and mitigation of disulphur decafluoride (S_2F_{10}), one of several toxic by-products formed by electrical discharges in the insulating gas sulphur hexafluoride (SF_6) used in power circuit breakers. The work is being conducted as a CRADA funded by DOE, EPRI, ESEERCO, BPA, the Tennessee Valley Authority, Ontario Hydro, and the Canadian Electrical Association. The total funding level over 3 years beginning October 1991 is \$1.8 million.

ORNL's Health and Safety Research Division has developed a cryo-enrichment measurement technique with a 10 parts per billion (ppb) detection sensitivity of S_2F_{10} in SF_6 . S_2F_{10} is a toxic substance with a critical threshold limit of 10 ppb. With the perfection of this technique, measurements can now be made to determine the levels of S_2F_{10} present in SF_6 insulating gas. Because much SF_6 gas-insulated electric power equipment is already in service in North America, particularly circuit breakers, ensuring safe operation and maintenance of this equipment is an important issue for the utility industry (also

see highlight, "Biological Effects of Electric and Magnetic Fields").

5.11 INTERNATIONAL TECHNOLOGY COOPERATION

ORNL is playing an increasingly important role in International Energy Technology Cooperation programs. These programs facilitate the exchange of energy technology information among North American, European, and industrialized Asian nations, as well as developing Asian Pacific nations.

Three such programs sponsored by DOE involve the exchange of energy technology-related information among International Energy Agency (IEA) member nations. The IEA Heat Pump Center constitutes an international network for the exchange of information on heat pumps with the objective of accelerating the implementation of heat pump technology, thereby optimizing the use of energy resources for the benefit of the environment. The IEA Center for the Analysis and Dissemination of Demonstrated Energy Technologies has a broader focus, sharing information about demonstra-

tion projects that have resulted in significant energy and cost savings. ORNL is the Operating Agent for Annex 19 of the Building and Community Systems Working Group of IEA. This Annex is developing a guidebook of good practices for insulated low-slope roof systems. ORNL's participation in these IEA program ensures that U.S. energy technology is appropriately presented in the information products on these energy technology cooperation programs, and that the information products and services provided by these IEA energy technology exchange centers are effectively disseminated to the public and

ORNL-Photo 5700-92

Fig. 5.19. High-phase-order demonstration project—6-phase line located in Binghamton, N.Y.

BIOLOGICAL EFFECTS OF ELECTRIC AND MAGNETIC FIELDS

Public concern about possible of health effects from power frequency electric and magnetic fields has grown dramatically. Accordingly, Congress approved legislation to form a National Electromagnetic Field (EMF) Research and Communications Program headed by the U.S. Department of Energy (DOE). Oak Ridge National Laboratory (ORNL) is DOE's lead laboratory for this program. DOE brought together experts from across the United States to lay out the goals and requirements of the National EMF Strategic Plan. This process is outlined in Fig. 5.20. DOE and ORNL held additional meetings with the public, federal and state agencies, and industry groups to ensure that the plan addresses the needs of all major stakeholders. A 5-year program of science and engineering research along with substantially increased public communications and policy components is planned.

ORNL provides technical coordination among researchers and between research organizations. Improving the free flow of information will result in more efficient program planning and use of resources. An important vehicle for technical coordination

is the Annual EMF Research Review. This technical meeting is organized by a steering committee with members from DOE, the National Institute of Environmental Health Sciences, the Electric Power Research Institute (EPRI), and New York State Public Service Commission. The ORNL EMF Program Manager serves as chairman. EPRI is the largest industry sponsor of EMF research, and ORNL has worked with EPRI to hold joint site reviews and workshops on special research topics. ORNL also participates in an international group of EMF program managers that meets annually to exchange information and maintains a data base of ongoing research.

The National Plan calls for increased EMF engineering research in areas of exposure assessment, dosimetry, field reduction, experimental quality assurance, field characterization, and instrumentation development. ORNL performs the quality assurance function with a team of scientists, who visit DOE-sponsored research sites to verify experimental procedures and exposure systems, and is beginning work in dosimetry and other engineering research areas. ♦

ORNL-DWG 93-5951

Fig. 5.20. Developing a National Electromagnetic Field (EMF) Plan.

private sectors in the United States that have a vested interest in energy efficiency and conservation.

During 1992, ORNL became involved in a new APEC Energy Project to advance the economic and social well-being of the Asian Pacific region through energy conservation and the application of energy-efficient technologies. During 1992, ORNL, in concert with DOE, developed a program of cooperation for the APEC Energy Project, Energy Efficiency and Conservation Theme, initiated design of a compendium of energy-efficiency and conservation measures, and put into operation a computerized *Energy Technology Document Data Base*.

Energy Division continued its role as technical advisor and evaluator for AID's Regional Office for Central America and Panama. The division is preparing an end-of-project evaluation of the Central American Rural Electrification Support Project, a regional effort that seeks to increase the access of rural populations to the benefits of electricity through conventional activities such as grid extension, as well as innovative approaches to providing credit to consumers and promoting increased productive use of electricity in these areas.

Energy Division also developed an innovative monitoring and evaluation system that will allow AID managers to determine the effectiveness of their efforts in natural resource management in Guatemala. AID's natural resource management program encompasses a wide variety of activities, from promotion of more sustainable agricultural practices to the creation of a National Park in the rain forests of the Peten. The monitoring and evaluation system developed by the division will measure progress toward improving the state of the natural resource base of Guatemala through a balanced approach to production and conservation.

The division continued management of a program to promote the widespread use of more efficient woodstove technology in Guatemala. The use of wood-burning cookstoves, widespread throughout Guatemala and many other parts of the developing world, is one factor that contributes to destruction of the natural resource base. By consuming less fuel for the same cooking requirements, efficient woodstoves can play

a role in reducing the high rates of deforestation in many developing countries.

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Developing **C**ountry **P**rogram

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DEVELOPING COUNTRY PROGRAM OVERVIEW

6.1 INTRODUCTION

In FY 1992, the mission of Energy Division's Planning and Coordination Office became focused more specifically on developing country programs, within both the division and Oak Ridge National Laboratory (ORNL) as a whole. In addition, the office continued to support the division's more general strategic planning and to play an active role in the educational reform process in the United States as part of ORNL's growing commitment to education.

6.2 DEVELOPING COUNTRY PROJECT ACTIVITIES

FY 1992 saw a major increase in project and program development activity. Within the division, the new Strategic Plan identified developing country research and development (R&D) as

one of four major emphases for the future (see Sect. 1 highlight, "Energy Division Strategic Plan"). The division organized a program of intensive Spanish-language training for selected staff, to be carried out early in FY 1993. During the year, Energy Division had five staff members resident in developing countries on assignments of a year or more: Sujit Das (Energy and Economic Analysis Section) in India; Glen Harrison (Center for Transportation Analysis) in Korea, on leave of absence with a Fulbright Fellowship; Keith Kline (Developing Country Program staff) in Guatemala; Carl Petrich (Integrated Analysis and Assessment Section) in Indonesia, on leave of absence with Lahmeyer International; and Dan Waddle (Efficiency and Renewables Research Section) in Bolivia, on leave of absence with the National Rural Electric Cooperative Association.

More generally, ORNL continued its strong support for developing country programs and

for expanded U.S. Department of Energy (DOE) roles in this area. ORNL's approved Institutional Plan included better energy technologies for the developing world and a center for global environmental studies as new initiatives. During FY 1992, the two associate laboratory directors most directly concerned with developing country programs, William Fulkerson and David Reichle, supported the exploration of directions for developing-country-related R&D programs through the ORNL Laboratory Director's R&D Program; and the Joint Institute for Energy and Environment was established in cooperation with the University of Tennessee and the Tennessee Valley Authority, partly to pursue international project opportunities that might benefit from the combined resources of these three institutions.

Meanwhile, DOE and other U.S. federal agencies showed increased interest in supporting R&D and technical assistance activities related to energy and environmental needs in developing countries, stemming from concerns about both global environmental change and U.S. export promotion. For example, a new DOE program was created, "Assisting the Deployment of Energy Practices and Technologies," based partly on a proposal by ORNL and the Lawrence Berkeley Laboratory; the interagency Committee on Renewable Energy Commerce and Trade (CORECT) was expanded to include energy efficiency improvement; a U.S.-Asia Environmental Partnership (US-AEP) was announced by the President and implemented by the U.S. Agency for International Development (AID); and a number of other activities were under development or expansion.

In this rapidly changing milieu, the division's Developing Country Program continued to emphasize energy efficiency improvement, environmental management, and biomass for energy, along with related topics of special interest to ORNL: institution building, technology transfer, and rural energy systems.

6.2.1 Energy-Efficiency Improvement

During FY 1992, Developing Country initiatives were aimed primarily at four targets: encouraging DOE program development,¹ contributing to the development of a training program strategy for the U.S. Working Group for Global Energy Efficiency (GEEI), assisting China in considering energy alternatives for a key "special economic zone," and working with a sister institution in India to develop a project for improving the efficiency of refrigerator technologies in that country.

In collaboration with DOE, the division worked with the Office of Technical Assistance (OTA), Office of Conservation and Renewable Energy (CE), as part of a multilaboratory consortium to develop an export assistance strategy for CE, and it was designated the coordinator for CE

activities in Asia. The division also assisted OTA in planning for a new interagency Committee on Energy Efficiency Commerce and Trade, established by the Energy Policy Act of 1992 as a partner of the well-established CORECT.

The Joint Institute for Energy and Environment was established to pursue international project opportunities.

In response to a request from the DOE Office of Energy Demand Policy, the division led the development of a concept paper for an Energy Efficiency Strategy Assistance Program (EESAP), headed by Ed Hillsman. EESAP is intended to help improve the institutional capabilities of developing countries to evaluate and implement energy-efficiency improvement programs.

Supported by the Office of Energy and Infrastructure of AID, the Developing Country Program continued to support GEEI, leading an effort to develop a broad strategy for increasing human resource development related to energy-efficiency improvement in developing countries. Central elements of the evolving strategy include improving endogenous training capabilities in developing countries and regions, improving the availability of appropriate training materials, and linking training with operational projects wherever possible.

CENTRAL AMERICAN RURAL ELECTRIFICATION SUPPORT PROJECT

Energy Division's John Shonder continued to lead Oak Ridge National Laboratory's (ORNL's) monitoring and evaluation activities for the Central American Rural Electrification Support (CARES) Project for AID's Regional Office for Central America and Panama (ROCAP). Based in Guatemala, this \$23 million, multiyear program seeks to increase the access of rural people in Central America to the benefits of electrical service through technical and managerial assistance to local and national utilities, promotion of productive uses of electricity, and assistance in developing financing for rural electrification projects.

One aspect of ORNL's involvement was the establishment of an autonomous electrical utility on the remote island of Roatán, Honduras (see map). With its pleasant climate, miles of unspoiled beaches, and the second-largest barrier reef in the world, Roatán has the potential to become a premier tourist destination. But economic development on the island has been stymied by the often unreliable electric power supplied by the national utility. With the assistance of the CARES program, residents formed the Roatán Electric Company, a broad-based consumer-owned utility. Local control and ownership have meant increased reliability of service and significant expansion of the system. The stage appears to be set for significant development of the tourism industry. This example of privatization of public utilities is seen as one method of alleviating power shortages that exist in many areas of

Central America and the rest of the developing world. ORNL's efforts have included designing a case study of the utility to examine the issues associated with its formation. This case study will be carried out as part of the formal evaluation of CARES, which will take place in 1993.

Other ORNL ROCAP activities during 1992 included making site visits to Guatemala, El Salvador, Honduras, and Nicaragua to monitor further project activities; serving as advisor to ROCAP in developing annual work plans and budgets; and providing on-call assistance to evaluate critical tasks. ♦

Central America, showing the remote island of Roatán off the coast of Honduras.

The most significant field project during the year was an assessment of energy options for Hainan Province, the largest of China's "special economic zones," led by Milton Russell and Larry Hill. The project emphasized potentials for integrated resource planning (IRP) in the electric power sector (Sects. 3.3.1 and 3.3.2). IRP applications were also explored in Eastern and Central Europe.

The most significant new project development initiative was an effort with the Tata Energy Research Institute in New Delhi, along with the International Institute for Energy Conservation, to develop a relatively high-efficiency home refrigerator technology for use in India (thereby reducing chlorofluorocarbon emissions, as well as emissions of CO₂ and other greenhouse gases from electric power production).

In addition, Tom Wilbanks, a Corporate Research Fellow, served as a member of the Energy Efficiency Committee of the U.S. Energy Association, which produced the report "Getting Down to Business: A Strategy for Energy Efficiency in the United States." Wilbanks was an invited speaker at the Third Annual Energy Conservation Forum at the National Press Club in Washington, D.C., which focused on developing-country markets for energy efficiency products and services.

6.2.2 Environmental Management

The division's principal developing-country initiatives involved creating a biosphere preserve in Guatemala, contributing to an improved understanding of land-use decisions related to deforestation in Brazil, surveying U.S. government activities related to technical cooperation with developing countries, and working to improve environmental management practices in Indonesia's electric power systems.

Energy Division's Keith Kline continued his leadership of the Mayarema Biosphere Preserve Project in Guatemala.² In FY 1992, the project emphasized institution-building in Guatemala, which is complicated by the need to balance

environmental and development priorities in a constantly changing institutional environment.

Supported by the ORNL Laboratory Director's R&D fund, Don Jones, Frank Southworth, and other division staff members collaborated with Environmental Sciences Division in a far-reaching research project on determinants, consequences, and policy implications of land-use decisions in Rondonia, Brazil. Understanding land-use decision making has been identified by the National Academy of Sciences (NAS) and others as perhaps the single most important research task related to the human dimensions of global change. This effort—combining insights from ecology, economics, anthropology, and geography—is an important contribution to the research community.

As a contribution to preparations for the 1992 United Nations Conference on Environment and Development, Ed Hillsman responded to an urgent request from the U.S. Department of State (with DOE funding) to prepare an inventory of U.S. ac-

tivities supporting environment and development in developing countries. Prepared under tight deadline pressure for distribution at an international meeting, the resulting survey was well received.³

In addition, Carl Petrich spent the year on leave of absence in Indonesia, leading a large World Bank-funded project to improve environmental management practices in the electric power sector in that country.

6.2.3 Biomass for Energy

In FY 1992, ORNL committed itself to developing a major program in biomass energy, the renewable energy source that falls most short of its potential for meeting developing-country needs for electricity, thermal energy, liquid fuels, and other modern energy delivery forms. In addition, the division developed proposals for biomass energy projects in China and Poland.

The most significant field project was an assessment of energy options for China's Hainan Province.

Energy Division contributed to development of ORNL's "biomass vision," primarily through Bob Perlack's insights about an integrated approach to biomass resource development and energy system use. This vision sees biomass as the major supply-side opportunity for meeting energy needs in a long-term sustainable manner in both developing and industrialized countries. The challenge is to take advantage of current biomass production and conversion approaches while attending carefully to environmental protection, institutional capabilities, and economic realities—especially given the seasonality of biomass production.

T. J. Wilbanks, R. D. Perlack, and S. B. Wright of Energy Division, together with J. W. Ranney of Environmental Sciences Division, initiated efforts to collaborate with the U.S. private sector in accelerating the commercialization of biomass energy technologies in developing countries. A meeting with leaders of the National Wood Energy Association (NWEA) in September led to the organization of a workshop in FY 1993 to develop a "call for action" for biomass energy programs, to reflect a consensus among energy analysts and private sector leaders about the importance of public/private collaboration in this area. NWEA is expected to issue the call for action in FY 1993.

6.2.4 Institution Building and Technology Transfer

The division also continued its leadership in research and technical assistance through institution building and technology transfer.^{4,5} Active in building institutional relationships with sister institutions in China, India, Russia, Pakistan, Poland, Guatemala, and Indonesia, the division also continued its active support for the energy programs of the Asia Pacific Development Centre, the leading regional energy planning institution in Asia.^{6,7}

In addition to being involved in developing the CE export assistance strategy, Energy Division assisted the U.S.-AEP in developing a strategic technology initiative in such areas as electricity-efficiency improvement and environmental technologies, emphasizing potential pay-

offs from technology adaptation to better fit Asian market conditions.

Tom Wilbanks also served as a member of the Atlantic Council Working Group on Energy Technology Transfer for Sustainable Economic Development, which reported its findings in September 1992;⁸ was an invited speaker at a Council on Foreign Relations study group on "Energy and Environment: The International Policy Issues"; and authored a chapter in the book *Global Climate Change: Implications, Challenges, and Mitigation Measures*.⁹

6.2.5 Renewable and Rural Energy Systems

Activity in renewable and rural energy systems continued to focus on the longstanding role of the Developing Country Program office as project monitor and evaluator for the Central American Rural Electrification Support Project of AID's Regional Office for Central America and Panama (ROCAP). With project efforts led by John Shonder, the division worked closely with ROCAP and its contractor, the National Rural Electrification Cooperative Association, to improve the project's focus and its prospects for documented positive outcomes (see highlight, "Central American Rural Electrification Support Project").

In addition, the Developing Country Program office continued to work with AID's Office of Energy and Infrastructure to define project activities under the auspices of AID's Renewable Energy Applications and Training project; Dan Waddle, on leave of absence from ORNL, spent the year leading a major rural electrification project in Bolivia.

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A b s t r a c t s o f **P** u b l i c a t i o n s

ABSTRACTS OF PUBLICATIONS

7.1 ABSTRACTS OF INTEGRATED ANALYSIS AND ASSESSMENT SECTION

[7.1.1] Multi-Purpose Exercises—More Bang for the Buck

M. V. Adler
K. S. Gant
R. A. Rowland^a

[Abstract of pp. 12–14 in *Journal of Civil Defense* **xxv**(3), 1992]

Exercises involving simulated emergencies provide opportunities for different emergency response organizations to practice and test their combined response. State and local governments receiving financial assistance from the Federal Emergency Management Agency under the Comprehensive Cooperative Agreements must conduct annual exercises demonstrating their response to different types of hazards. Federal and industrial installations have their own exercise requirements, as do other facilities

such as hospitals and airports. Combining exercise efforts can reduce the total number of required exercises and enhance the realism of the response. Joint exercise planning efforts increase the interaction among facilities and community response groups and promote an integrated community response.

Research sponsored by the U.S. Department of Energy.

^aFederal Emergency Management Agency, Chemical Preparedness Division.

ORNL-Photo 9345-90

Joint planning exercises like this one can reduce the total number of required exercises and enhance the realism of the response.

[7.1.2] Multi-Purpose Exercises: Making DOE Exercises Meet State and Local Exercise Requirements

M. V. Adler
K. S. Gant
R. A. Rowland^a

(Abstract of *Proceedings of the 15th Annual TRADE Conference*, St. Petersburg, Fla., November 18–20, 1991)

Exercises provide opportunities for different emergency response groups to practice their combined response. State and local governments receiving financial assistance from the Federal Emergency Management Agency under Comprehensive Cooperative Agreements must hold regular exercises demonstrating their response to different types of hazards. The U.S. Department of Energy and other federal and industrial installations have exercise require-

ments, as do hospitals and airports. Combining exercise efforts can help state and local responders satisfy their exercise requirements while reducing the total number of required exercises, enhancing the realism of the response, and promoting an integrated community response.

Research sponsored by the U.S. Department of Energy.

^aFederal Emergency Management Agency, Chemical Preparedness Division.

[7.1.3] Potential Contribution of the Clean Coal Program to Reducing Global Emissions of Greenhouse Gases

T. J. Blasing

(Abstract of pp. 1–16 in *Proceedings of the 85th Annual Meeting and Exhibition of the Air & Waste Management Association*, Kansas City, Mo., June 21–26, 1992)

The U.S. Department of Energy's Clean Coal Program (CCP) is a government and industry co-funded effort to demonstrate a new generation of more efficient, economically feasible, and environmentally acceptable coal technologies. To demonstrate the feasibility of the various clean coal technologies (CCTs), several "show-case" facilities are being constructed at selected locations throughout the United States. The best and most promising CCTs will then be advanced in terms of technical, environmental, and economic performance to the point where the private sector can introduce them into the commercial marketplace. Environmental considerations of CCP initially focused on reducing emissions of sulfur dioxide and nitrogen oxides to the atmosphere. However, some CCTs may contribute appreciably to reducing emissions of carbon dioxide (CO₂), thereby diminishing the rate of any global warming that may result from greenhouse effects. This is particularly true for CCTs involving replacement of a major portion

of an existing facility or providing the option of using a different fuel form (the repowering CCTs). Because the subject of global-scale climate warming is receiving increased attention, the effect of CCTs on CO₂ emissions has become a topic of increasing interest. The *Final Programmatic Environmental Impact Statement for the Clean Coal Technology Demonstration Program* projected that with full implementation of those repowering CCTs that would be most effective at reducing CO₂ emissions (pressurized fluidized bed and coal gasification fuel cell technologies), the national fossil-fuel CO₂ emissions by the year 2010 would be roughly 90% of the emissions that would occur with no implementation of any CCTs by the same date. This paper examines the global effect of such a reduction in greenhouse gas emissions and compares that effect with effects of other strategies for reducing global greenhouse gas emissions.

Research sponsored by the U.S. Department of Energy.

[7.1.4] Environmental Assessment, Combustion Engineering Integrated Coal Gasification Combined Cycle Repowering Project

T. J. Blasing	R. L. Miller
C. W. Hagan	W. P. Staub
L. N. McCold	J. G. Smith ^a
G. W. Suter ^a	

(Abstract of DOE/EA-0444, Oak Ridge National Laboratory, March 1992)

On December 22, 1987, Public Law No. 100-202, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes," was signed into law. Among other things, the act provided funding to the Department of Energy (DOE) to cost-share the design, construction, and operation of innovative clean coal technology (ICCT) projects to

demonstrate the feasibility of technologies that reduce emissions of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) from coal combustion. Emissions of SO₂ and NO_x have been identified as contributors to acidic deposition ("acid rain") both nationally and internationally. The ICCT Program is part of DOE's Clean Coal Technology (CCT) Demonstration Program. On February 22, 1988, DOE issued Program Opportunity Notice

(PON) Number DE-PS01-88FE61530 for Round II of the CCT Program. The purpose of the PON was to solicit proposals to conduct cost-shared ICCT projects to demonstrate technologies capable of being commercialized in the 1990s, more cost-effective than current technologies, and capable of achieving significant reduction of SO₂ or NO_x emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution. The Combustion Engineering (C-E) Integrated Coal Gasification Combined Cycle (IGCC) Repowering Project was one of 16 proposals selected by DOE for negotiation of cost-shared federal funding support from among the 55 proposals received in response to the PON. The ICCT Program has developed a three-level strategy through compliance with the National Environmental Policy Act (NEPA) consistent with the President's Council on Environmental Quality regulations implementing NEPA (40 CFR 1500-1508) and the DOE guidelines for compliance

with NEPA (10 CFR 1021). This strategy includes the consideration of programmatic and project-specific environmental impacts during and subsequent to the project selection process. As the first level, DOE published and publicly distributed a Programmatic Environmental Impact Analysis (PEIA) for the ICCT Program (DOE/PEIA-002) in September 1988. The PEIA assesses the impacts of all technologies proposed to be demonstrated under the ICCT Program. As a second level, before project selection, DOE prepared a confidential project-specific analysis for internal DOE use in the decision-making process. This Environmental Assessment, which represents the third level of NEPA review, provides a site-specific analysis of the expected environmental impacts of the proposed C-E IGCC Repowering Project.

Research sponsored by the U.S. Department of Energy.

^aEnvironmental Sciences Division.

[7.1.5] Cultural Resources Survey and Management Plan of the Clear Air Force Station, Clear, Alaska

C. R. Boston
N. H. Bigelow^a
F. E. Goebel^a

W. R. Powers^b
R. B. Braid
I. E. Treitler^c

(Abstract of ORNL/M-2365, Oak Ridge National Laboratory, November 1991)

This report presents the findings of a 5-day cultural resource survey of the Clear Air Force Station (CAFS), Clear, Alaska. The survey took place from August 8 through August 12, 1991. Two major goals of this fieldwork were to (1) conduct a reconnaissance-level archaeological survey of CAFS for prehistoric and historic cultural resources, and (2) examine the potential for future discovery of cultural resources on the base. CAFS, located about 25 km (15.5 miles) south of the village of Nenana, is situated near the southern edge of the Tanana Flats, a broad plain stretching 50 km (30 miles) from the foothills of the Alaska Range northward to the Yukon-Tanana Uplands. Archaeologically, the Nenana Valley is the richest area of interior Alaska. At least 100 prehistoric and historic sites have been discovered along its course, from its

source at the Nenana Glacier to its mouth at Nenana, a distance of approximately 225 km (140 miles). These sites range from 100 years old to as much as 12,000 years old and include some of the oldest cultural remains yet found in the Americas (Walker Road, Dry Creek, Moose Creek). The earliest sites, assigned to the Nenana Complex, are Paleoindian in character and display many similarities with early Clovis sites found on the High Plains of the western United States. Denali Complex microblade sites (dating 10,000–7,000 years ago), Northern Archaic sites (6,000–3,000 years ago), and Late Denali sites (3,000–1,000 years ago) have also been found in the Nenana Valley, as have dozens of Late Prehistoric and Historic period sites. Significantly, of the prehistoric sites found thus far along the Nenana River, none are located on the

Tanana Flats between Rex Bridge and Nenana where CAFS is located. Before the present survey, the area in the vicinity of CAFS had not been examined for cultural resources. Past research in the Nenana Valley has been limited to survey and excavation of sites in the foothills zone.

Research sponsored by the U.S. Department of the Air Force.

^aUniversity of Alaska.

^bUniversity of Wisconsin.

^cUniversity of Tennessee.

[7.1.6]

Defense Against Biological Terrorism

C. V. Chester

(Abstract of article in *Proceedings of the Annual Meeting of Doctors for Disaster Preparedness*, Costa Mesa, Calif., July 11, 1992)

Iraq's use of chemical agents in its war against Iran and threatened use of biological weapons against the United States and its allies in the Gulf War resurrected interest in these types of weapons. Skillfully used, they can produce effects comparable to nuclear effects at a fraction of the cost. Production of the agents is within the resources of almost any nation state, including those in the Third World. While these agents can be delivered by ballistic missiles, they are delivered far more effectively by low-flying aircraft or surface trucks that can deploy a crosswind line source at ground level. Biological terrorism against the United States could include clandestine attacks by a sociopathic individual, a domestic extremist group, a foreign-supported extremist group, or a foreign terrorist group. Overt attack of the United States with lethal agents would be extremely irrational given the recent performance of the U.S. military in the Persian Gulf and in Panama. The most efficient avenue of attack would be via an aerosol clandestinely deployed upwind of a population concentration or other target under stable meteorological conditions. Agents could be used to contaminate food, medicines, cosmetics, beverages, and drinking water. This type of attack, however, would have little military or economic significance; it would be spread out too much in time and affect too few people. Public health services would rapidly discover that there was an epidemic and remove the contaminated product(s) from commercial channels. To produce significant casualties, an aerosol attack would be required over a population center. One of the

most severe natural obstacles to the use of biological agents is the loss of virulence in the agent used on culture and handling. Also, with reasonable supportive care, even serious epidemics of lethal diseases have some survivors. The most difficult problem for the deployment of biological weapons is the almost universal propensity for nonspore organisms to lose effect when exposed to the air, especially in conjunction with sunlight and smog. Micrometeorology becomes very important in the effectiveness of biological weapons in attempts to get large area coverages. Biological aerosols tend to deposit on foliage, to flow around hills rather than going over them, and to flow around or over urban heat islands. Complex targets like cities with high-rise buildings would take heavy doses to overcome all of the real-world losses of agent in the complex geometry of a city. For the individual attempting to reduce his vulnerability to terrorist use of biological weapons, the surest method is to pressurize one's living spaces with air that has been drawn through a high-efficiency particulate air filter. Standard commercial-grade filters costing a little more than \$100 are capable of removing 99.97% of aerosol particles of 0.3 μ m size at a flowrate of 1000 ft³/min. An individual also could encourage tree planting on a wide scale in his area or move into an area that is heavily covered with trees, and move out of areas that are attractive targets (such as the affluent suburbs of Washington, D.C.). Part of the U.S. defense budget supports a Biological Defense Research Program, a research and development program funded by the Army to

develop vaccines for some of the more lethal communicable diseases such as the hemorrhagic fevers, at the U.S. Army Medical Research Institute of Infectious Diseases at Ft. Detrick in Frederick, Maryland. At the Army Chemical Research Development and Engineering Center at Edgewood, Maryland, research, development, and engineering activities are used to develop nonmedical defenses against biological warfare. Tests of agents are conducted at Dugway Proving Ground 80 km (50 miles) southwest of Salt Lake City, Utah. U.S. government responses to a biological terrorist threat are prescribed by a number of executive orders and other policies. In general, emergency responses of the different government departments in the administrative branch are governed by Executive Order 12656. Coordination is the responsibility of the Federal

Emergency Management Agency. Terrorist incidents occur in the United States much less frequently than in Europe, and far less frequently than in the unstable parts of the world such as the Mideast. This is variously ascribed to the effectiveness of the U.S. internal security forces (the FBI and Bureau of Alcohol, Tobacco, and Firearms) and the isolation from Europe and the Mideast provided by the Atlantic Ocean. The few attempts to use toxic weapons against the general public have been limited to isolated sociopaths producing only a few fatalities from contaminated pharmaceuticals. To plan and carry out a large-scale clandestine biological attack would require a rare degree of technical and administrative skill.

Research sponsored by the U.S. Department of Energy.

[7.1.7]

Issues in NEPA Implementation

J. T. Enslinger

[Abstract of p. 7 in *Issues in NEPA Implementation Newsletter* 17(4), September 1992]

Much has been accomplished in the 22 years since the signing of the National Environmental Policy Act (NEPA). In its present form, NEPA calls for a balanced approach to planning, with environmental issues being given equal consideration with other types of planning concerns. Because of NEPA, federal agencies are certainly more aware that environmental concerns must be addressed at some point in their planning processes. However, a recent survey of NEPA practitioners indicated that many members of this group believe that several deficiencies exist in the NEPA implementation processes of some federal agencies. According to the survey responses, the principal deficiencies are the following: (1) the tendency to use environmental impact statements (EISs) as decision-implementation rather than decision-making documents; (2) the lack of effective planning and follow-up concerning mitigation measures identified by the NEPA process; and (3) NEPA overkill, particularly in the preparation of extensively detailed environmental assessments (EAs). The causes of the deficiencies are varied and complex; however, one cause often cited by the survey respon-

dents was the lack of firm NEPA guidance and oversight. The incorporation of NEPA into the decision-making processes of federal agencies has been left, to a large degree, to the discretion of the individual agencies themselves. Thus, in some cases, other concerns such as financial, technical, and political issues have been assigned higher priority in the decision-making process. In such situations, NEPA may be addressed cursorily as an afterthought, or it may be viewed simply as an administrative box to be checked off. Conversely, in some cases, the procedural aspects of preparing EAs and EISs may unduly override the planning intent of the law, resulting in excessive, complex, and confusing documentation, or "NEPA overkill." Either of these approaches indicates a misunderstanding of NEPA, while neither is conducive to serious planning and follow-up concerning mitigation measures for potential environmental impacts. In these circumstances, the tendency seems to be to look to the regulatory agencies for help. In fact, the overall results of the survey indicate that more stringent regulations and oversight may be required to bring about the

implementation of the full intent of NEPA. There is currently some encouraging evidence of increased activity on the part of the President's Council on Environmental Quality in these areas. Realistically, however, there is a limit to the resources available for such activities. All the answers cannot be provided by the federal regulators. Therefore, NEPA practitioners must take advantage of every resource and opportunity to help bridge the gap between the current misconceptions concerning NEPA and its true intent. These may include placing emphasis on communicating with each other by sharing new ideas and methods through meetings and the open literature; making special efforts to im-

prove communications with management and sponsors requiring NEPA assessments; taking advantage of training opportunities and devising methods to transfer new knowledge gained to colleagues involved with the NEPA process vertically throughout the company or agency; and becoming active in the various committees of the NEPA Working Group of the National Association of Environmental Professionals who are addressing current NEPA issues. The key is being concerned and involved as NEPA practitioners so that all can benefit from the experiences of others.

Research sponsored by the U.S. Department of Energy.

[7.1.8] On-Site Interim Storage of Spent Nuclear Fuel: Emerging Public Issues

D. L. Feldman

(Abstract of pp. 143-51 in *Proceedings of 3rd International High Level Radioactive Waste Management Conference*, Vol. 1, American Nuclear Society, LaGrange, Ill., April 12, 1992)

Failure to consummate plans for a permanent repository or above-ground interim monitored retrievable storage facility for spent nuclear fuel has spurred innovative efforts to ensure at-reactor storage in an environmentally safe and secure manner. This article examines the institutional and socioeconomic impacts of dry cask storage

technology, an approach to spent fuel management that is emerging as the preferred method of on-site interim spent fuel storage by utilities that exhaust existing storage capacity.

Research sponsored by the U.S. Nuclear Regulatory Commission.

[7.1.9] Tracking Global Climate Change Policy

D. L. Feldman

[Abstract of pp. 1-5, in *Policy Currents* 1(4), November 1991]

Projected impacts of global warming include damage to coastal areas from rising sea level and more intense tropical storms, higher incidence of heat-related disease, destruction of fragile ecosystems, depletion of fresh water, more urban smog, and massive shifts in world food production. This article discusses implications of these impacts for political scientists in three areas: policy making under conditions of uncertainty and potentially high risk, the ability of political institutions to adapt to long-term environmental change, and the impacts of worldwide energy and other consumption patterns on

choices facing future generations. The article concludes that the prospect of global warming raises troublesome questions about the risks of human activities on climate and about the degree to which the public should trust "experts." Because of the high uncertainty surrounding global warming, concern has been raised that alarmists may be promoting a hidden agenda to obtain media attention or more research dollars. Given this uncertainty on the one hand, and the potentially high risks of inaction on the other, policy makers need to facilitate a vigorous, many-sided debate on this issue; design flexible

policies; characterize the magnitude of risks from global warming to allow comparison with more familiar environmental hazards such as toxic wastes or air pollution; encourage better research on the benefits, costs, and administrative impacts of various strategies for preventing global warming; and consider whether policy lessons can be transferred from states to the national government. Political scientists need to

help develop evaluation strategies for measuring the effectiveness of long-term policies to manage global warming. Effectiveness should not be measured by how quickly global warming is reduced, which may be unmeasurable in our lifetime, but to what degree prudent risk reduction strategies become an established part of the policy landscape.

Research sponsored by the U.S. Department of Energy.

[7.1.10] From Nuclides to Nerve Gas: The Development of the Chemical Stockpile Emergency Preparedness Program

K. S. Gant
M. V. Adler

(Abstract of article in *Proceedings of the 15th Annual TRADE Conference*, St. Petersburg, Fla., November 18–20, 1991)

The U.S. Army and the Federal Emergency Management Agency established the Chemical Stockpile Emergency Preparedness Program (CSEPP) to improve emergency preparedness around each location storing the nation's aging stockpile of unitary chemical weapons. CSEPP requires that a series of exercises be conducted at each location on a regular schedule. The CSEPP exercise program drew upon the existing

Army and civilian exercises. Merging the exercise traditions of both the communities and installations into a joint exercise program acceptable to both sides, coupled with the particular nature of this hazard, required a number of adjustments in the usual approaches.

Research sponsored by the Federal Emergency Management Agency.

[7.1.11] Projecting Regional Patterns of Emission Allowance Trading

E. L. Hillsman
D. R. Alvic^a

(Abstract of article in *Proceedings of the Annual Meeting of the Association of American Geographers*, San Diego, April 19–22, 1992)

Much of the political support for the Acid Deposition Control title of the Clean Air Act Amendments (CAAA) of 1990 reflected a desire to reduce sulfur dioxide emissions from power plants in the Ohio River basin, as a way of reducing acid deposition in the Northeast. Formulas for allocating emission allowance would reduce emissions by plants in five basin states from 40% of 16.2 million tons in the mid-1980s to 30% of 8.9 million tons in 2000. However, CAAA allows utilities to undercontrol emissions

if they can purchase additional allowances from other utilities that overcontrol emissions. This system of allowance trading has the potential to augment or counteract the original regional intent of the legislation, depending on costs of compliance equipment, costs of low-sulfur coal, and state policies to influence compliance strategies. This report develops a model to project compliance options, including allowance trading, by individual utilities within an allowance trading system, and presents projections of the

impact of allowance trading on the regional patterns of sulfur dioxide emissions.

Research sponsored by the U.S. Bureau of Mines and the U.S. Department of Energy.

^aUniversity of Tennessee.

[7.1.12] Local/Regional Policies: Acting Globally by Thinking Locally

E. L. Hillsman

(Abstract of conference presentation, *Global Climate Change: Linking Energy, Environment, Economy, and Equity*, Washington, December 5-6, 1991)

Policies to reduce greenhouse gas emissions from present levels will require changes in local and regional decision making as well as in decisions made at national and multinational scales. A number of cities and states have taken action to reduce emissions either directly or as a by-product of solving local problems such as air quality. These initiatives represent a potential resource to be mobilized in national policy. Case studies are under way to understand the decision making involved and its implications, and to identify ways that national policy might support and benefit from local efforts. Preliminary results from the first of these case studies indicate that reductions in greenhouse gas emissions may be greater when set as a direct target than when resulting as a byproduct of other local problem solving.

Research sponsored by U.S. Department of Energy, Office of Environmental Analysis.

Changes in SO₂ in 2000 emissions relative to base case scenario when conservation is limited to the ten shaded states.

[7.1.13] Technology Cooperation Related to Global Climate Change: A Selected Inventory

E. L. Hillsman

(Abstract of ORNL/M-1810, Oak Ridge National Laboratory, December 1991)

The possibility that man-made emissions of greenhouse gases contribute to global climate change requires all countries to seek a more sustainable path to economic growth and development. To respond to this challenge, a global partnership needs to be established based on cooperation among all countries—a partnership designed to promote environmentally sound and sustainable growth, wise management of natural resources, and efficient use of our industrial capacity all around the world. Technology cooperation with developing countries (and

countries with economies in transition) constitutes a crucial element in the international community's efforts to respond to global climate change. Such cooperation should address both hard and soft technology needs and should include priority concerns, such as technology needs assessment, technology development, technical assistance, training, and institution or capacity building, as well as traditional technology transfer. In calling for a cooperative process, the authors recognize that the successful transfer of knowledge, know-how, or machinery de-

depends on a two-way relationship based on mutual interests and benefits and that it relies heavily on the creativity and dynamism of the private sector. The proper role of government is to promote and facilitate this process. Governments have already initiated a considerable range of activities involving technology cooperation related to global climate change. To provide a clearer picture of existing resources, the United States has compiled the following selected inventory of activities in this area. The inventory covers energy efficiency, energy supply, agriculture, forestry and natural resources, climate science, coastal zones, and other activities, which demonstrates that considerable cooperation is already under way and that improved coordination of existing resources may be one of the most

cost-effective response measures to take. Although estimating the total cost of such U.S.-sponsored activities is difficult, an initial survey indicates that expenditures were well above \$97 million in FY 1991. A prospective look at upcoming budgets confirms that this amount will grow with a clearer understanding of the science of climate change and the measures individual countries adopt in response. Concerns about climate change provide an important opportunity to strengthen cooperation among growing nations to create a cleaner, more prosperous future for the planet. This inventory is intended to contribute to the further development of that process.

Research sponsored by the U.S. Department of Energy Office of Environmental Analysis.

[7.1.14] Estimated Increases in the Cost of Electricity Under Three Acid-Rain Control Bills

E. L. Hillsman
D. R. Alvic^a

(Abstract of *Proceedings of the 1991 Applied Geography Conference*, Toledo, Ohio, October 23-27, 1991)

Several bills were introduced in the past two Congresses to reduce emissions of sulfur dioxide and nitrogen oxides from electric power plants. The effects of these bills on electricity costs depend on features of the bills, on the mix of generating capacity owned by different electric utilities, on the technologies available for complying with the legislation, and on the time horizon used to calculate the costs. A system of computer software has been developed to make utility-specific estimates of the effects of different legislation on electricity costs. This paper presents sample results from a larger analysis of six pieces of legislation. These results suggest that the emissions trading systems proposed in some legislation, and adopted in the Clean Air Act Amendments of 1991, may have less effect than expected on the cost of complying with the legislation.

Research sponsored by the U.S. Bureau of Mines.

^aUniversity of Tennessee.

Summary of emission rates and model results.

[7.1.15] Migration of a Groundwater Contaminant Plume by Stratabound Flow in WAG 1, ORNL

R. H. Ketelle

R. R. Lee

(Abstract of ORNL/ER-126, Oak Ridge National Laboratory, August 1992)

The discovery of radiologically contaminated groundwater in core hole 8 in the western portion of Waste Area Grouping (WAG) 1 at Oak Ridge National Laboratory (ORNL) prompted a detailed investigation to identify the contaminant plume. Using a working hypothesis of stratabound groundwater flow and contaminant transport, existing subsurface geologic data were analyzed to predict the contaminant plume discharge location in First Creek and locations of contaminated groundwater seepage into storm drains. The hypothesis states that differential lithologic/fracture conditions lead to the development of preferred flow and transport pathways, of discrete vertical extent, which may not be coincident with the hydraulic gradient. Leakage out of the stratabound pathway is a minor component of the overall plume configuration. Results of the analysis indicate that application of the stratabound pathway hypothesis leads to an accurate prediction of the plume discharge location in First Creek, which was 65° oblique to the general gradient in that portion of WAG 1. Plume identification subsequently provided

an explanation for historical contamination in WAG 1 piezometers and water-quality wells that previously was not understood. Analysis of the subsurface storm drain in the vicinity of the plume also provided an explanation for historical contamination in storm drain outfalls to First Creek and verification of the comparatively minor role of upward leakage out of the stratabound pathway to the water table as described by the hypothesis. Characterization of a groundwater contaminant plume in the western portion of WAG 1 at ORNL will be used as input to remediation alternatives and for additional investigations to more fully describe both the three-dimensional character of the plume and its source location. The development of a highly accurate, predictive capability in groundwater contaminant migration at ORNL, demonstrated by the results of this study, will be applied to ongoing numerical groundwater analyses at ORNL and at other WAGs on the Oak Ridge Reservation.

Research sponsored by the U.S. Department of Energy.

[7.1.16] Performance Assessment of Low-Level Radioactive Waste Disposal at Oak Ridge National Laboratory

D. W. Lee

D. C. Kocher^a

(Abstract of pp. 46-66, *Proceedings of the Symposium on Waste Management*, Tucson, Ariz., March 1-5, 1992)

A site-specific, long-term performance assessment is being conducted for the currently operating low-level waste disposal facility at Oak Ridge National Laboratory. Disposal facilities must comply with performance objectives for low-level waste disposal specified in DOE Order 5820.2A. This paper describes (1) the assumptions used in the draft performance assessment;

(2) the results of the analysis in regard to compliance of disposal facilities with the requirements for protection of off-site members of the public, inadvertent intruders, and groundwater resources; and (3) modifications of the performance assessment and waste operations that are being developed for demonstrating compliance

with the performance objectives with reasonable assurance.

Research sponsored by the U.S. Department of Energy.

^aHealth and Safety Research Division.

[7.1.17]

D2PC Sensitivity Analysis

D. P. Lombardi

(Abstract of ORNL/TM-12134, Oak Ridge National Laboratory, August 1992)

The Chemical Hazard Prediction Model (D2PC) developed by the U.S. Army will play a critical role in the Chemical Stockpile Emergency Preparedness Program by predicting chemical agent transport and dispersion through the atmosphere after an accidental release. To aid in the analysis of the output calculated by D2PC, this sensitivity analysis was conducted to provide information on model response to a variety of input parameters. The sensitivity analysis focused on six accidental release scenarios involving chemical agents VX, GB, and HD (sulfur mustard). Two categories, corresponding to conservative most likely and worst case meteorological conditions, provided the reference for standard input values. D2PC displayed a wide variety of sensitivity to the various input parameters. The model displayed the greatest overall sensitivity to wind speed, mixing height, and breathing rate. For other input parameters, sensitivity was mixed but generally lower. Sensitivity varied not only with parameter, but also over

the range of values input for a single parameter. This information on model response can provide useful data for interpreting D2PC output.

Research sponsored by the Federal Emergency Management Agency.

Variable skin penetration factor—Scenario 1.

[7.1.18]

NEPA's Challenge: A Leadership Role for the NAEP

L. N. McCold

[Abstract of article in *NEPA Working Group Newsletter*, National Association of Environmental Professionals, 1992 (also published as "Implementing NEPA's Purposes: A Leadership Role for the NAEP" in *NAEP Newsletter* 16(6), January 1992)]

In the last issue of this newsletter, Carl Bausch summed up the frustration many National Environmental Policy Association (NEPA) practitioners feel with the way NEPA is often implemented: "perfunctorily after program or project plans are in place." He compared this situation with the purposes of NEPA that include promoting "efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."

He concluded that, "vitalizing the NEPA process requires a change in society's way of thinking about that process, not necessarily in Council on Environmental Quality's (CEQ's) implementing regulations...." A society's commitment to preserving its environment is essential to the success of any efforts to "prevent or eliminate damage to the environment." In the United States, commitment to the environment has become the norm—most Americans consider themselves to

be environmentalists. Leadership and clear ideas about how to implement NEPA earlier in the program and project planning processes are the missing elements. To this point, CEQ and the courts have set the standards for acceptable NEPA practice. However, CEQ need not always be the fountainhead of new ideas for implementing NEPA. Environmental professionals doing NEPA work have experience that complements that of the CEQ staff. New ideas for improving the NEPA process should be coming from us. And many new ideas do come from us—at our annual conference, in the journal, and at our work places. However, as environmental professionals we can and should do more. We can take a leadership role in developing improved ways to implement NEPA. Professionals set high standards for themselves. By setting standards, they set the pace for all those who would work in the field. I propose that the National Association of Environmental Professionals (NAEP) take the lead at developing *voluntary national consensus standards* for NEPA practice within the American National Standards Institute (ANSI) framework. Developing national standards requires a significant effort and a commitment from NAEP, but the benefits for the profession, for NAEP, and for us as individual NEPA practitioners could more than outweigh the costs.

Developing standards can take many routes. NAEP could develop standards of practice for NEPA activities as an extension of our Standards of Practice for Environmental Professionals. An extension of our current Standards of Practice would be relatively easy to develop and might have influence well beyond NAEP members, but they would be much less credible than national standards. Essentially all national standards are ANSI standards, which means that they were developed following ANSI procedures. ANSI procedures allow standards to be developed by three alternate methods, but each method is time consuming and requires a high level of public input. Developing national standards would have to be performed under the supervision of a NEPA standards committee, and if we pursued national standards, NAEP would need to adopt ANSI procedures or their equivalent. Developing standards for NEPA practice could be a function of a committee of the NEPA Working Group. Most of the effort would be by volunteers, but NAEP would incur administrative costs such as those associated with meetings and communications. (Legal issues may also need to be considered.) Grants to support some of these costs might be available.

Research sponsored by the U.S. Department of Energy.

[7.1.19] The Clean Coal Program's Contributions to Addressing the Requirements of the Clean Air Act Amendments of 1990

R. L. Miller

(Abstract of pp. 1–23 in *Proceedings of the Annual Meeting of the Air & Waste Management Association*, Kansas City, Mo., June 21–26, 1992)

This paper examines the potential contributions of the U.S. Department of Energy's Clean Coal Program (CCP) to addressing the requirements of the Clean Air Act (CAA) Amendments of 1990 (CAAA). Initially funded by Congress in 1985, CCP is a government and industry co-funded effort to demonstrate a new generation of more efficient, economically feasible, and environmentally acceptable coal technologies in a series of full-scale "showcase" facilities built across the country. CCP is expected to provide funding for more than \$5 billion of projects during five

rounds of competition, with at least half of the funding coming from the private sector. To date, 42 projects have been selected in the first four rounds of CCP. CAA and amendments form the basis for regulating emissions of air pollutants to protect public health and the environment throughout the United States. Although the origin of CAA can be traced back to 1955, many amendments passed since that time are testimony to the iterative process involved in the regulation of air pollution. Three key components of CAAA, the first major amendments to

the CAA since 1977, include mitigation measures to reduce levels of (1) acid deposition, (2) toxic air pollutants, and (3) ambient concentrations of air pollutants. This paper focuses on the timeli-

ness of clean coal technologies in contributing to these provisions of CAAA.

Research sponsored by Department of Energy Office of Fossil Energy.

[7.1.20]

Reliability-Centered Maintenance of Power Transformers and Circuit Breakers

S. L. Purucker
R. T. Goeltz

K. Hemmelman^a
R. Price^a

(Abstract from article in *Proceedings of EPRI Computer-Assisted Technologies for NDE & Plant Monitoring Workshop*, Philadelphia, August 10-13, 1992)

The Bonneville Power Administration (BPA) historically has maintained high-voltage equipment, including transformers and power-circuit breakers, on a time-driven basis. This equipment has served BPA's needs in the past; however, newer methods will be needed to effectively maintain the power system in future years. Aging equipment, maintenance backlogs, and budget constraints currently exist. BPA has initiated a research and development project to examine reliability-centered maintenance (RCM) as an alternative to time-based maintenance on high-voltage equipment. Under RCM, the performance of each piece of equipment will be monitored by observing many operating parameters. For example, with circuit breakers, the trip time, accumulated contact wear using I²T, the mechanism's timing, and several other parameters will be observed (measured). Equipment performing below a predetermined level or equipment accumulating a large amount of

"usage" will receive maintenance. The maintenance will restore full performance and preserve an acceptable service life for that piece of equipment. To develop and evaluate RCM concepts, BPA is installing a prototype system at its Alvey Substation on 4 transformers and 25 breakers. The Alvey prototype will be used to elaborate on the basic principles of RCM as applied to high-voltage equipment and to provide the basis for a design that could be used across the BPA power system. The present schedule calls for completion of the monitoring system by fall of 1992 and development of the RCM algorithms for the equipment by fall of 1993. The system will be evaluated for a period of time beginning in fall of 1993 to finalize the algorithms and develop a system-wide implementation strategy if warranted.

Research sponsored by the U.S. Department of Energy.

^aBonneville Power Administration

[7.1.21] Feasibility Study: Application of RCM Techniques for Substation Maintenance at the Bonneville Power Administration

S. L. Purucker
B. E. Tonn
R. T. Goeltz
D. T. Rizy

J. W. Van Dyke
D. R. James^a
S. Kerckel^b
M. L. Simpson^b

(Abstract of ORNL/TM-12051, Oak Ridge National Laboratory, May 1992)

This feasibility study examines reliability-centered maintenance (RCM) as it applies to the Bonneville Power Administration (BPA) substa-

tion maintenance program. Reliability techniques are examined and evaluated, existing BPA equipment maintenance procedures are

As equipment gets older, maintenance becomes increasingly important.

documented, equipment failure history is considered, economic impacts are estimated, and

various equipment instrumentation methods are reviewed. Based on this analysis, a prototype system is proposed. The prototype will be implemented in two phases. Phase 1, completed in 1992, includes instrumenting one power transformer and one oil circuit breaker. Software development will focus on displaying data. Phase 2 is to be completed the following year. The remaining transformers and breakers will be instrumented during the second phase. Software development will focus on predictive maintenance techniques and maintenance decision support.

Research sponsored by Bonneville Power Administration and the U.S. Department of Energy.

^aHealth and Safety Research Division.

^bInstrumentation and Controls Division.

[7.1.22] The Context and Organization of Demand-Side Management Collaboratives: An Overview

M. Schweitzer
J. Raab^a

(Abstract of article in *Proceedings of ACEEE Summer Study*, Asilomar, Calif., August 1992)

Since 1988, many utilities and nonutility parties (NUPs) (such as consumer advocates, environmental groups, and state energy offices) across the country have tried a new approach to reaching an agreement on demand-side management (DSM) program design and policies. This new approach, called a DSM collaborative process, attempts to reach consensus among oftentimes adversarial parties instead of using traditional litigation. This paper describes key contextual and organizational characteristics of collaboratives using data collected during a recent study of 9 cases of DSM collaboration involving 24 utilities and approximately 50 NUPs in 10 states. A lengthier report presents the full breadth of findings from that study, including a detailed analysis of the successes and failures of the collaboratives. Based on a review of the relevant literatures on integrated resource planning and dispute resolution and on the authors' experience, four categories of contextual and organizational variables were chosen for study: (1) the

regulatory and legal history of the collaborative, (2) the parties involved and those excluded, (3) the scope of the collaborative, and (4) the collaborative process. Regulatory and legal history includes the factors leading to initiation of the collaborative and the historic ability of different participating parties to influence the decisions made by state public utility commissions. Key characteristics of the parties involved and excluded include the types of participants, their expectations and willingness to compromise, and the attributes of those who did *not* participate. The scope covered overall collaborative goals and key issues tackled by the collaborative. The variables selected in the process arena include organization structure, the use of outside consultants, and the use of consensus.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aRaab Associates, Boston.

[7.1.23] Draft Functional Requirements for the Chemical Stockpile Emergency Preparedness Program Automated Emergency Management Information System

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W. N. Naegeli^a
J. H. Reed^b

(Abstract of report, Oak Ridge National Laboratory, September 1992)

The purpose of this document is to define the overall functional requirements for an emergency management information system to meet the needs of the Chemical Stockpile Emergency Preparedness Program (CSEPP). This document provides the basis for the development of system requirements documents for both on-post and off-post applications. These functional requirements build on the capabilities of existing and previous systems, such as the Integrated Base-line System. Several candidate emergency management information systems are available from public and private sources, but each of these systems has significant limitations that reduce its

effectiveness for the CSEPP. These limitations include incomplete planning modules, inadequate resource-tracking capability, and inability to generate and track standard operating procedures. The desired functions described in this document will be used to evaluate currently available systems and determine what additions to those systems may be necessary, as well as to guide the design of any new system components that are required.

Research sponsored by U.S. Department of the Army.

^aConsultant.

^bWisconsin Demand-Side Demonstrations, Inc.

[7.1.24] Assessment of the Need for Dual Indoor/Outdoor Warning Systems and Enhanced Tone Alert Technologies in the Chemical Stockpile Emergency Preparedness Program

J. H. Sorensen

(Abstract of ORNL/TM-12095, Oak Ridge National Laboratory, May 1992)

This report analyzes the need for a dual indoor/outdoor warning system as recommended by the program guidance and Alert and Notification (A&N) standard for the Chemical Stockpile Emergency Preparedness Program. Under the current program standards, the outdoor warning system consists of omnidirectional sirens, and the new indoor system would be an enhanced tone alert (TA) radio system. This analysis identifies various tone-alert technologies, distribution options, and alternative siren configurations. It also assesses the costs and benefits of the options and analyzes what appears to best meet program needs. Given current evidence, the report recommends that a 10-dB siren system and the special or enhanced TA

radio be distributed to each residence and special institution in the immediate response zone

Path model of evacuation dynamics.

as the preferred A&N standard. This approach minimizes the cost of maintenance and cost of the TA radio system while providing a high degree of reliability for indoor alerting. Further-

more, it reaches the population (residential and institutional) with the greatest need for indoor alerting.

Research sponsored by the U.S. Department of the Army.

[7.1.25] Modeling Protective Action Decisions for Chemical Weapons Accidents

J. H. Sorensen
G. O. Rogers^a
M. J. Meador^b

(Abstract of article in *Proceedings of the SCS Simulation 1992 MultiConference*, Orlando, Fla., April 6, 1992)

Oak Ridge National Laboratory has developed a simulation model to evaluate various protective action strategies for chemical weapons accidents. The Protective Action Evaluator for Chemical Emergencies (PAECE) model generates estimates of downwind dosage given an accident scenario and exposure reduction given a scenario of human response to the emergency. Embedded in the system is the Army's gaussian plume atmospheric dispersion code for chemical agents. The initial model was a single-run version operating under the DOS operating system. To analyze a scenario, one must input the entire data set each time the model is run. The user interface is cumbersome, not allowing for near real-time application in an emergency. In September 1991, a version was released capable of comparing two protective actions at 5 different

downwind distances. Additionally, the user can change a single parameter and re-run the model or load a predefined scenario and run the model. This version runs under the Macintosh operating system and is programmed in THINK C. This paper describes the logic structure of the model and demonstrates the new user interface for the model that allows rapid assessment of protective-action strategies. A hypothetical accident situation will be simulated, and the PAECE model will be used to choose among two different protective-action strategies. Future modeling directions are also discussed.

Research sponsored by the Federal Emergency Management Agency.

^aTexas A & M University.

^bUniversity of Tennessee.

[7.1.26] When Shall We Leave?: An Empirical Examination of Factors Affecting the Timing of Evacuation Departures

J. H. Sorensen

[Abstract of pp. 153-65 in the *International Journal of Mass Emergencies and Disasters*, Special Evacuation Issue 9(2), 1991]

This paper represents the first known attempt to statistically examine individual variation in the timing of warning receipt and evacuation departure. The paper documents what is known about the timing of departures across different emergency events. A general model of evacuation dynamics is then specified. This is followed by

an effort to model individual variations in warning receipt and evacuation departures in the Nanticoke, Pennsylvania, hazardous material fire. While conclusive evidence exists that such variation will occur in the individual receipt of warning and departure times, the reasons behind individual differences are still somewhat

Diffusion of warning at Nanticoke: when people heard warning by warning-system type.

inconclusive. The single most important factor in determining when people will leave is when they are warned. Little of the variance in the timing of warning receipt or mobilization time could be explained by the model. Of greater interest are the factors that did or did not covary with time of warning receipt or mobilization time. The most significant finding was that the

time of warning receipt varied by the way people received the warnings. The second most important finding was that personalization of the message led to a decreased time to respond. This presents a minor dilemma to the emergency official because personalized warning mechanisms have slower dissemination times. Also important were the factors that were not significant. Neither age or family size was related to either time of warning receipt or mobilization time. That older people are not significantly delayed in hearing and responding adds more to the controversy about whether the elderly are more vulnerable to disaster. While proximity was significantly related to when the warning was received, the evacuation strategy was a time-phased evacuation. People at greater distance mobilized as quickly as those close in. Furthermore, level of perceived threat did not lead to faster response.

Research sponsored by Federal Emergency Management Agency.

[7.1.27]

Preparing EBS Messages

B. M. Vogt
J. H. Sorensen

(Abstract of ORNL/TM-12163, Oak Ridge National Laboratory, September 1992)

Warning messages transmitted to populations at risk from an accidental release of chemical agent must be designed carefully to maximize appropriate responses from affected publics. This guide develops an approach for preparing Emergency Broadcast System (EBS) messages for the Chemical Stockpile Emergency Preparedness Program. Sample messages illustrate the application of this approach. While the sample mes-

sages do not cover every emergency situation, the texts are generic in that accident- and location-specific factors can be incorporated into the final message developed by local emergency planners. Thus, they provide a starting point, not an end product, for emergency planners.

Research sponsored by the Federal Emergency Management Agency.

[7.1.28] Model for Impedance of an Ionic Conductor Sandwiched Between Blocking Electrodes

J. C. Wang

(Abstract of article in *Proceedings of the Second International Symposium on Electrochemical Impedance Spectroscopy*, Santa Barbara, Calif., July 12-17, 1992)

The simplest model for the impedance of an ionic conductor sandwiched between two blocking electrodes is a resistor in series with a capacitor (re pair) representing the bulk material and the conductor-electrode interface, respectively, and a second capacitor parallel to the re pair representing the electronic dielectric response of the system. In practice, to describe the experimental data satisfactorily, one needs to replace the interface capacitor with a constant-

phase-angle (CPA) element and add a non-Debye dielectric element parallel to the resistor to represent the local ionic movement. In this paper, some of the existing physical models for the CPA and non-Debye dielectric elements are discussed, and an example is presented for analyzing the impedance data using the resultant circuit model.

Research sponsored by the U.S. Department of Energy.

[7.1.29] Imaging Algorithms for Geophysical Applications of Impedance Tomography

A. J. Witten
J. E. Molyneux^a

(Abstract of pp. 177 in *Proceedings of Inverse Problems in Scattering and Imaging*, San Diego, July 19-24, 1992)

The methods of impedance tomography may be employed to obtain images of subsurface electric conductivity variations. For practical reasons, voltages and currents usually are applied at locations on the ground surface or down a limited number of boreholes, but almost never over the entire surface of the region being investigated. The geophysical inversion process can be facilitated by constructing algorithms adopted to these particular geometries and to the lack of complete surface data. In this paper, the fluctuations in conductivity are assumed to be small compared with the background value. The imaging of these fluctuations is carried out exactly within the constraints imposed by the problem geometry. Several possible arrangements of injections and monitoring electrodes

are considered. In two dimensions, these include: cross-line geometry, current input along one line (borehole) and measurements along a separate parallel line; single-line geometry, injection and monitoring using the same borehole; and surface reflection geometry, all input and measurement along the ground surface. Theoretical and practical limitations on the image quality produced by the algorithms are discussed and are applied to several sets of simulated data. The images produced are displayed and analyzed.

Research sponsored by the U.S. Environmental Protection Agency.

^aWidener University.

[7.1.30] Field Studies in Geophysical Diffraction Tomography

A. J. Witten
S. Stevens

R. Price^a
W. C. King^a

J. Ursic^b

(Abstract of article in *Proceedings of Inverse Problems in Scattering and Imaging*,
San Diego, July 19–24, 1992)

Geophysical diffraction tomography (GDT) is a quantitative, high-resolution technique for subsurface imaging. This method has been used in a number of shallow applications to image buried waste, trenches, soil strata, tunnels, synthetic magma chambers, and the buried skeletal remains of *seismosaurus*, the longest dinosaur ever discovered. The theory associated with the GDT inversion and implementing software has been developed for acoustic and scalar electromagnetic waves for bistatic and monostatic

measurements in cross-borehole, offset vertical seismic profiling and reflection geometries. This paper presents an overview of some signal-processing algorithms, a description of the instrumentation used in field studies, and selected imaging results.

Research sponsored by the U.S. Environmental Protection Agency.

^aU.S. Military Academy, West Point.

^bU.S. Environmental Protection Agency, Region 5.

[7.1.31] High Resolution Image Processing of Geophysical Data with Diffraction Tomography

A. J. Witten
W. C. King^a
J. Ursic^b

(Abstract of article in *Proceedings of the Army Science Conference*, Orlando, Fla., June 22–25, 1992)

The need to detect buried objects, locate subsurface voids, or obtain detailed information concerning subsurface structures spans many technical disciplines, including environmental and geotechnical engineering as well as military programs such as tunnel detection and unexploded ordnance disposal. Technology has been developed that employs wave probing techniques to sense subsurface features. Ground-penetrating radar (GPR), seismic refraction, and electromagnetic conductivity have demonstrated success; however, technical limitations primarily in information processing have limited the general applicability of each of these methods. This paper discusses an enhanced signal-processing procedure that can be applied to existing remote-sensing technology to greatly expand its detection and imaging capabilities. The paper

presents a derivation of the Generalized Projection Slice Theorem (GPST), which is the basis for geophysical diffraction tomography, a high-resolution subsurface imaging procedure. The technique is then applied to other field surveying methods such as GPR. The paper concludes by combining the theory of GPST with a statistically based search algorithm to demonstrate that detection of known features can be accomplished at preselected high confidence levels using the same field systems, but with considerably less data collection.

Research sponsored by the U.S. Department of Energy and the U.S. Environmental Protection Agency.

^aU.S. Military Academy, West Point.

^bU.S. Environmental Protection Agency Region 5.

[7.1.32]**Diffraction Tomography in Geosciences**

A. J. Witten
J. E. Molyneux^a
W. C. King^b

(Abstract of *Proceedings of South Eastern Conference on Theoretical and Applied Mechanics*,
Nashville, Tenn., April 12–14, 1992)

Tomographic imaging is most well known through its applications in diagnostic medicine. In the 1970s, CT scanners were commercialized and are now routinely used in all major medical centers. The success of these devices, in part, stimulated the pursuit of new applications for tomography and the development of new signal-processing algorithms. One particularly prolific area of tomographic research is in geosciences. These efforts have been motivated by needs in traditional applications of geophysics, such as resource exploration and enhanced recovery, and more recent concerns such as the subsurface characterization required for environmental restoration. The earliest major initiative in geophysical tomography considered the application of CT-type signal-processing algorithms to seismic measurements. These algorithms are based on the assumption of straight-ray paths, and the imaging procedure is referred to as back-projection because an image is formed by projecting data back through the imaged region from measurement point to source. Unfortunately, the straight-ray path assumption becomes invalid at the longer wavelengths of geophysical seismic energy. As a result, straight-ray-based geophysical tomography yields blurred images of large features. Smaller features may not be resolved, particularly when they occur in inhomogeneous host formations. More recently, research has been directed toward signal-processing algorithms that account for the ray bending associated with wave propagation in geophysics. One widely used approach is iterative ray tracing. In this procedure, straight-ray backprojection is employed to provide an initial distribution of spatial

variations in wave speed. Based on this spatial distribution, revised curved-ray paths are defined by forward modeling. A revised image is constructed by backprojection along the new ray paths. This iterative process of forward modeling and backprojection continues until some convergence criterion is satisfied. Another approach to wave-based imaging, which is the subject of this paper, is geophysical diffraction tomography (GDT). Currently, GDT is not a commercially deployed remote-sensing technology; however, it has provided excellent results in a number of field applications. These include imaging of buried wastes, trenches, pipes, tunnels, soil strata, and the skeletal remains of the longest dinosaur ever discovered. The focus of this paper is on both new applications of GDT and new theoretical developments based on GDT. One particular aspect discussed is the problem of detection of specific subsurface features. A means to address such a problem is maximum likelihood estimation theory. Another element of this paper considers the application of vector waves to geophysical remote sensing. Rather than endeavor to invert the full vector wave equation, the authors consider this equation as a means to infer the three-dimensional structure of subsurface features from one-dimensional measurements by probing with orthogonally polarized waves. Also considered is the extension of GDT to non-wave-based measurements, allowing its implementation with other tools of geoscience.

Research sponsored by the U.S. Department of Defense.

^aWidener University.

^bU.S. Army.

[7.1.33] Cultural Resources Management Plan of the Eldorado Air Force Station, Schleicher County, Eldorado, Texas

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C. R. Boston

I. E. Treitler^a
W. E. Moore^b

(Abstract of ORNL/M-2364, Oak Ridge National Laboratory, July 1992)

The United States Air Force (USAF) is required by Air Force Regulation (AFR) 126-7 and Section 110 of the National Historic Preservation Act (NHPA) to document (and if necessary protect) all cultural resources located at its facilities. NHPA protects cultural resources that are listed, or are deemed by the State Historic Preservation Officer to be eligible for listing, on the National Register of Historic Places (NRHP). These resources may be prehistoric, historic, or "traditional cultural properties" (i.e., features of the natural landscape used in the traditional cultural practices of a group of people, most often Native Americans). Where NRHP-eligible properties are identified on USAF property, USAF is required by AFR 126-7 to develop a cultural resources management plan outlining the appropriate action for the protection of these resources. From January 23 through January 27, 1992, an archaeological survey and assessment of Eldorado Air Force Station in Schleicher County, Texas, was conducted to bring USAF into compliance with AFR 126-7 and Section 110. USAF property at Eldorado covers approximately 49 ha (120 acres). Preparation for the field assessment included archival research into other Schleicher County sites. The study included a field check of previously recorded sites, 41SL10 and 41SL14,

and a survey of areas not investigated previously. Two prehistoric sites were found during the survey and have been recorded with the Texas Archeological Research Laboratory (TARL) in Austin, Texas, as 41SL18 and 41SL19. Both sites are lithic scatters located in the uplands along the western edge of the mesa overlooking the South Concho River Valley. Surface-collected artifacts suggest the area was occupied during the Archaic and Late Prehistoric periods. Site 41SL18 is considered to possess significant research potential and has been recommended for testing. Sites 41SL10, 41SL14, and the portion of 41SL19 on USAF property are not considered eligible for the NRHP. All artifacts and records pertaining to this project have been placed in permanent curation at TARL. Two alternatives are recommended for site management: site protection or data retrieval. The alternative selected will depend on the prospects for alternation of the site as a result of construction. Because no construction is anticipated, the protection alternative is recommended.

Research sponsored by the U.S. Department of the Air Force.

^aUniversity of Tennessee.

^bBrazos Valley Associates.

[7.1.34] Assessment of the Exposure Index as a Means of Predicting Potential Consequences Associated with Nuclear Power Plant Accidents

M. Yambert
M. Linn

(Abstract of ORNL/NRC/LTR-92/10, Oak Ridge National Laboratory, March 1992)

An analysis was performed to demonstrate the ability of the exposure index (EI) correlations used in the Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437) to predict consequences associ-

ated with atmospheric releases from postulated nuclear power plant accidents. This was accomplished by comparing the values for early and latent fatalities and total dose that were predicted from EI values to those generated with the

Calculation of Reactor Accident Consequences 2 "Staff Version" (CRAC2S) computer code (NUREG/CR-5264). The results showed that, in all cases, the EI correlations provided reasonable

and conservative estimates for the consequences calculated by CRAC2S.

Research sponsored by the U.S. Nuclear Regulatory Commission.

7.2 ATRACTS OF ENERGY AND ECONOMIC ANALYSIS SECTION

[7.2.1] Estimation of Small Business Activity by County for the National Infrastructure Information System (NIIS)

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T. N. Yoder^b

(Abstract of ORNL/TM-12114, Oak Ridge National Laboratory, September 1992)

The Federal Emergency Management Agency (FEMA) has commissioned the design of an assessment system to perform rapid analysis of the economic impacts of various disasters. Oak Ridge National Laboratory developed the National Infrastructure Information System (NIIS) in response to this need. Its design includes several modules to support emergency assessment: (1) the Facility Damage Assessment Module, to provide rapid summaries of economic capacity at risk in a disaster area; (2) the Regional Impacts Module (RIM), to estimate the change in a region's production, consumption, and net exports as a result of capacity lost in the disaster area; (3) the Inter-Regional Trade Flows Module, to identify potential interruptions in commodity trade flows between regions, based on the results of the RIM analysis; and (4) the National Economic Model, to identify potential macroeconomic impacts of the disaster. In addition to the assessment system, FEMA needs a core data base that contains the comprehensive, county-level information required to conduct regional and national impact analyses. The effort is focused on a general overview of the seriousness of each disaster (e.g., how large the relative impact is) and not on detailed local effects. However, the core data file must be complete

enough and accurate enough to support analysis of the relative costs of different disasters. Coverage must be comprehensive to address equity issues, as well as detailed in the specific industries that most affect the economy's ability to respond to disaster. The files used to construct the current NIIS core file have been evaluated for completeness of coverage, both by Standard Industrial Classification and by size of establishment. No major industry must be overlooked, and the substantial economic activity of small establishments must be represented in the NIIS system. Because the primary purpose of the NIIS system is to evaluate the impact on economic activity, summary data can provide the most comprehensive coverage in the minimum amount of storage space. This document addresses the specific evaluation of small business coverage in the Dun and Bradstreet "Twenty-Plus" file, in *County Business Patterns*, and the methods by which *County Business Patterns* data were used to supplement small business coverage in the core NIIS file.

Research sponsored by the Federal Emergency Management Agency.

^aScience Applications International Corporation.

^bUniversity of Tennessee.

[7.2.2] Marketable Permits for Controlling Sulfur Dioxide Emissions

D. J. Bjornstad
D. R. Hale^a

(Abstract of ORNL/TM-11787, Oak Ridge National Laboratory, December 1991)

During the summer and fall of 1990, the U.S. Congress met in conference committee to reconcile differences in proposed amendments to the Clean Air Act. One issue was the definition of a marketable permit scheme to reduce sulfur dioxide emissions from about 16 million tons per year in 1987 to no more than 8.9 million tons per year in 2001. Under the proposed legislation, the federal government would distribute permits to large sellers of electricity, mainly utilities, who would either "spend" the permits as they emitted sulfur dioxide or trade the permits if their emissions fell below their permit allotments. The proposed distribution of permits would be sufficient to cover a portion of historical emissions of existing power plants, but other large sellers of electricity, including independent power producers, would be required to obtain permits either through direct purchases or through federally sponsored auction. Because a facility could emit sulfur dioxide only if its holdings of permits were sufficient to cover its emissions, the permits would become an economic resource much like capital, labor, and fuel. Emitters would trade off the costs of more expensive fuel containing less sulfur or more expensive pollution

control equipment against the cost of purchasing permits. In this way, the bills' sponsors hoped to achieve efficiencies in pollution control similar to those commonly found in markets for private goods. This paper describes research sponsored by the Energy Information Administration at the Oak Ridge National Laboratory concerning the nature of the auctions described in the bills. The research was undertaken at the request of the House Committee on Energy and Commerce to assess how various provisions in the bills might affect the workings of the market. Because the project called for the analysis of market mechanisms that do not currently exist, a "laboratory" approach was applied in which artificial markets were created using computerized trading, volunteer subjects, and cash incentives to mimic the markets being studied. Dr. Mark Isaac, at the University of Arizona, and Dr. Jamie Kruse, at the University of Colorado, led teams that designed and conducted the laboratory experiments.

Research sponsored by the U.S. Department of Energy, Energy Information Administration.

^aU.S. Department of Energy, Energy Information Administration.

[7.2.3] Energy Security, Public Policy, and the Role of the DOE Office of Energy Emergencies

D. J. Bjornstad
T. R. Curlee
D. R. Bohi^a

(Abstract of ORNL/TM-11788, Oak Ridge National Laboratory, November 1991)

This paper addresses the concept of energy security, the costs and benefits of energy security, and policies that could potentially alter these costs and benefits. These issues are considered from the perspective of the Department of Energy's Office of Energy Emergencies (OEE) to

determine if alternative or additional roles should be open to OEE. The approach taken is limited to the economic costs and benefits of energy security, reflecting the view that the bulk of important energy security issues can at least be approached from this perspective. This paper

begins by defining a generic energy emergency, one that can be applied to virtually all energy forms and that includes most circumstances commonly thought to constitute an emergency. An energy emergency results from a sudden change in the quantity, market price, or social value of energy, in combination with a domestic or worldwide energy system that cannot rapidly adjust to that change. The definition is carefully stated because mitigating the impacts of such events is not always necessary, nor is it uniquely a governmental responsibility. In fact, the first recourse in emergency preparedness should always belong to the private sector. However, government should deal with three different aspects of energy emergency activities. First, it should condition the decision-making environment by seeing that adequate information about energy conditions is available and that its own policy position is clear. Next, government should evaluate the preparedness measures undertaken by the private sector. In doing this, government should apply two measures—efficiency and equity. The efficiency measure seeks to determine whether businesses and consumers

have adequately assessed the trade-offs between the current costs that must be accepted in exchange for uncertain future benefits if an energy emergency occurs. In applying the equity measure, government must see that the burdens of an emergency are not distributed unfairly. Finally, if it finds private-sector preparation to be inadequate, government has a variety of direct and indirect means with which to intervene. One direct measure currently used is the buildup and drawdown of the strategic petroleum reserve. Other measures include contingency plans to override market allocations during wartime, as might be developed under the graduated mobilization response. Indirect means include a variety of tax and transfer schemes that alter existing private sector incentives to prepare. Well-conceived monetary and fiscal policies complete the tools. Policies in which government relies totally on government allocations should be reserved for extraordinary circumstances.

Research sponsored by the U.S. Department of Energy Office of Energy Emergencies.

^aResources for the Future.

[7.2.4] The Cost of Silicon Nitride Powder: What Must It Be to Compete?

S. Das
T. R. Curlee

[Abstract of ORNL-6694, Oak Ridge National Laboratory, February 1992 (Also published as "The Cost of Silicon Nitride Powder and the Economic Viability of Advanced Ceramics," pp. 1103–1111 in *American Ceramic Society Bulletin* 71(7), July 1992)]

The ability of advanced ceramic components to compete with similar metallic parts will depend in part on current and future efforts to reduce the cost of ceramic parts. This paper examines the potential reductions in cost that could result from the development of less expensive advanced ceramic powders. The analysis focuses specifically on two silicon nitride engine components—roller followers and turbocharger rotors. The results of the process-cost models developed for this work suggest that reductions in the cost of advanced silicon nitride powder from its current level of about \$20 per pound to about \$5 per pound will not in itself be sufficient to lower the cost of ceramic parts below the

current cost of similar metallic components. This work also examines whether combinations of lower-cost powders and further improvements in other key technical parameters to which costs are most sensitive could push the cost of ceramics below the cost of metallics. Although these sensitivity analyses are reflective of very optimistic technical improvements, the resulting part costs are estimated to remain higher than similar metallic parts. These findings call into question the widely held notion that the cost of ceramic components must not exceed the cost of similar metallic parts if ceramics are to be competitive. Economic viability will ultimately be decided not on the basis of which part is less costly, but on

an assessment of the marginal costs and benefits provided by ceramics and metallics. This analysis does not consider the benefits side of the equation. Findings on the cost side of the equation suggest that the competitiveness of ad-

vanced ceramics will ultimately be decided by the ability to evaluate and communicate the higher benefits that advanced ceramic parts may offer.

Research sponsored by the U.S. Department of Energy.

[7.2.5] Navy Mobility Fuels Forecasting System Report: World Petroleum Trade Forecasts for the Year 2000

S. Das

(Abstract of ORNL-6683, Oak Ridge National Laboratory, December 1991)

The Middle East will continue to play the dominant role of a petroleum supplier in the world oil market in the year 2000, according to business-as-usual forecasts published by the U.S. Department of Energy. However, interesting trade patterns will emerge as a result of the democratization in the former Soviet Union and Eastern Europe. U.S. petroleum imports will increase from 46% in 1989 to 49% in 2000. A significantly higher level of U.S. petroleum imports (principally products) will be coming from Japan, the former Soviet Union (FSU), and Eastern Europe. Several regions (the Far East, Japan, Latin America, and Africa) will import more petroleum. Much uncertainty remains about the

level of future Soviet crude oil production. FSU net petroleum exports will decrease; however, the United States and Canada will receive some imports from the former Soviet Union because of changes in the world trade patterns. The FSU can avoid becoming a net petroleum importer as long as it (1) maintains enough crude oil production to meet its own consumption; (2) is able to participate in world petroleum trade; and (3) maintains its existing refining capacities. Eastern Europe will import approximately 50% of its crude oil from the Middle East.

Research sponsored by the U.S. Navy Energy and Natural Resources Office, Office of Naval Research, U.S. Department of the Navy.

[7.2.6] Environmental Quality Information Analysis Center Multi-Year Plan

S. Das
R. G. Rivera^a
T. E. Walsh^b

(Abstract of ORNL/TM-12098, Oak Ridge National Laboratory, September 1992)

Costs for environmental cleanup-related goods and services have increased over the past decade, partly because of increased technology costs for remediation and for facility waste operations. Federal agencies have a mission to carry out environmental cleanup and compliance. Technology is an important factor in those activities because it can help agencies comply with environmental requirements at a lower cost. As a result, demand is growing for available technology alternatives for solving environmental problems and for research and develop-

ment in areas where practical solutions do not exist. An information analysis center (IAC) is a federal resource that provides technical information for a specific technology field. An IAC links an expert technical staff with an experienced information specialist group, supported by in-house or external data bases to provide technical information and maintain a corporate knowledge in a technical area. An IAC promotes the rapid transfer of technology among it users and provides assistance in adopting new technology and predicting and assessing emerging technol-

ogy. This document outlines the concept, requirements, and proposed development of an Environmental Quality IAC (EQIAC). An EQIAC network is composed of several nodes, each with specific technology capabilities. This document also outlines strategic and operational objectives for the phased development of one such node of an EQIAC network and makes recommendations for developing and implementing an initial EQIAC node within the U.S. Air Force using this Air Force case study to develop operational requirements and cost estimates for an EQIAC node. EQIAC's mission is to serve as an

authoritative, full-service center providing information, technical expertise, and analysis capabilities in environmental quality technology to support federal environmental operations. In the Air Force case, EQIAC's initial emphasis will be on analysis to support developers and planners in the research, development, and acquisition organization.

Research sponsored by the U.S. Department of Energy.

^aRDG, Inc.

^bUniversity of Florida.

[7.2.7] Environmental Quality Information Analysis Center (EQIAC) Operating Procedures Handbook

S. Das

T. E. Walsh^a

(Abstract of ORNL/TM-12144, Oak Ridge National Laboratory, August 1992)

The *Operating Procedures Handbook of the Environmental Quality Information Analysis Center (EQIAC)* is intended to be kept current as EQIAC develops and evolves. Its purpose is to provide a comprehensive guide to the mission, infrastructure, functions, and operational procedures of EQIAC. The handbook is a training tool for new personnel and a reference manual for existing personnel. The handbook will be distributed throughout EQIAC and maintained in binders containing current dated editions of the individual sections. It will be revised at least annually to reflect the current structure and

operational procedures of EQIAC. This initial version, dated July 1992, describes EQIAC in the projected Full Operational Capability mode. This mode may not be achieved for at least 2 years. The Initial Operational Capability may be achieved by the fourth quarter of 1992 with a cadre of personnel who will become the supervisory heads of the subgroups of EQIAC described in this handbook.

Research sponsored by the U.S. Department of Energy.

^aUniversity of Florida, Gainesville.

[7.2.8] Energy, Economic Reform, and Capital Requirements in the Soviet Confederation and Eastern Europe: Challenges and Opportunities

L. J. Hill

(Abstract of ORNL-6680, Oak Ridge National Laboratory, July 1992)

Capital requirements for energy in the Commonwealth of Independent States (formerly the Soviet Union, excluding the three Baltic republics) and Eastern Europe are conservatively estimated to exceed \$700 billion over the next decade, more than \$600 billion of which is required by the Commonwealth. These energy-related re-

quirements compete with capital needed for alternative uses, including funds to modernize most existing industries, to develop new industries that are internationally competitive, and to provide consumer goods denied to centrally planned economies over the past several decades. Although policymakers are historically re-

luctant to give up ownership of the means of production, the only viable option to obtain the necessary development capital is to make the foreign investment environment as attractive as possible. This presents attractive energy-related investment opportunities for U.S. firms engaged in every aspect of the energy business because capital is needed for more than just energy exploration and production. In fact, most capital is required downstream from these activities, including the transmission, distribution, and storage of various energy forms. Significant opportunities also exist to improve the efficiency of both producing and consuming energy. Investments in energy efficiency improvements have a potential that is vast, economic, and exploitable over fairly short planning horizons. And, for most of the countries, the short term is crucial. If an imbalance exists between capital supply and capital requirements in energy sectors, energy capacity shortfalls caused by insufficient capital can lead to stagnating economies over the medium term. Over the long term, lack of sufficient capital to develop modern energy sectors impedes not only economic growth but also development of the economic infrastructure needed to sustain growth. This study addresses potential medium- and long-term problems in the energy sectors of Eastern Europe and the

Commonwealth, looking at capital requirements and potential sources of capital over the next decade. Capital requirements for the coal, oil, gas, and electricity subsectors are estimated in two parts: (1) replacing the portion of the existing capital stock expected to depreciate over the decade and (2) increasing the capital stock to service additional energy production. Resources to satisfy these requirements include (1) foreign capital such as loans and credits from multilateral assistance banks, foreign borrowing, direct foreign investment, and bilateral assistance from the industrialized countries and (2) domestic savings. The electric power sector is the most attractive for *public* assistance from the industrialized countries because: (1) it is projected to have the highest growth rate of any of the energy sectors in these economies; (2) regional and global environmental concerns about high-sulfur coal and nuclear power plants focus special attention on the power sector; (3) the electric power sector has the largest potential for savings in percentage terms from energy management activities; and (4) the power sector is one of the least likely sectors to attract foreign, private-sector investment, denying it new technologies and management techniques that other energy sectors may benefit from.

Research sponsored by the U.S. Department of Energy.

[7.2.9] How Urbanization Affects Energy Use in Developing Countries

D. W. Jones

(Abstract of pp. 621–630 in *Energy Policy* 19, September 1991)

This paper identifies mechanisms whereby urbanization affects energy consumption. Industrialization and urbanization accompany each other during economic development, but urbanization exerts a number of independent influences on energy use. It permits economies of scale in production but requires more transportation. Food must be transported to urbanized populations, and relatively smaller agricultural populations must modernize, entailing considerable increases in agricultural energy

use. In cities, a number of production activities that were domestically provided in rural areas, using human or animal energy, shift to sources outside the household, using modern energy sources. The largest single source of change in energy use is personal transportation. Passenger transport in cities is heavily weighted towards fuel-using modes, particularly as incomes increase. To assess the overall impact, a regression analysis of 59 developing countries for 1980 is conducted. Holding constant per capita in-

come and the extent of industrialization, the elasticity of energy consumption per capita and per dollar of gross domestic product is between 0.35 and 0.48.

Research sponsored by the U.S. Department of Energy.

[7.2.10] Forces Shaping Energy Consumption in Five Latin American Nations, 1985–2000

D. W. Jones

(Abstract of pp. 277–299 in *OPEC Review*, Autumn 1991)

This paper projects growth of national energy consumption in five major Latin American countries—Argentina, Brazil, Colombia, Mexico, and Venezuela—from 1985 through 2000. Major forces influencing growth in energy consumption in Latin America are per capita income growth, urbanization, industrialization, rural development, and population growth. Electrification and development of transportation systems are included as elements of the other major components of development. Elasticities of energy consumption per capita with respect to income growth, urbanization, and industrialization are applied to projections of the evolution of those variables to obtain upper- and lower-bound estimates of growth in per capita energy consumption by the year 2000. Application of projected population growth yields projections

of growth in national energy consumption in the respective countries. Best-estimate projections say that by the year 2000, most of these countries could consume 40 to 90% more energy than they did in 1985. The total-range projections extend from 23 to 128%. By far the greatest parts of these increases are attributable to population growth. Next in order of magnitude of contribution is per capita income growth, which is conservatively assumed to average 1% per year for each country for the remainder of the century. The next largest contributing factor is urbanization. In Brazil, Colombia, and Mexico, urbanization is a strong contender with per capita income growth. Industrialization is the weakest contributor overall but could exert strong influences in Brazil and Colombia.

Research sponsored by the U.S. Department of Energy.

[7.2.11] An Introduction to the Thünen Location and Land Use Model

D. W. Jones

(Abstract of pp. 35–70 in *Research in Marketing Supplement 5*, JAI Press, Inc., 1991)

The Thünen model of land-pricing and the location of spatially continuous activity relies on transportation costs to generate an array of spatially variable relative prices. The variation in relative prices induces different economic choices at different locations that, in turn, yield spatially variable densities of various activities and zones of different activities. The model originally was applied to agricultural problems, but it forms the basis of contemporary, urban

spatial models. This paper introduces the logic of the Thünen model, in an agricultural setting, with a simple exposition of land-pricing and land use with a single activity and fixed production coefficients. The exposition is generalized to a general production function allowing factor substitution among labor, capital, other purchased inputs, and land.

Research sponsored by the U.S. Department of Energy.

**[7.2.12] Endogenous Environmental Degradation and Land Conservation:
Agricultural Land Use in a Large Region**

D. W. Jones
R. V. O'Neill^a

(Abstract of pp. 79–101 in *Ecological Economics* 6, 1992)

This paper studies endogenous land conservation and maintenance in agriculture in a large region with fixed population and endogenous wage. Farmers allocate labor between cultivation on the one hand and conservation and maintenance on the other to maximize output while compensating for depressing effects of cultivation practices. This paper compares large-region results with those for a small region with fixed wages and endogenous population. Higher product prices and larger populations worsen environmental degradation throughout a region and contribute to deforestation. An exogenous increase in the wage in a small region reduces cultivated area but may increase or decrease equilibrium land degradation. In a large region, greater technical interaction in production between agricultural inputs reduces the impact of population and price increases on deforestation. Higher input prices take degra-

dation pressure off land, whether the total population is fixed or variable. Improvements in transportation unambiguously worsen environmental deterioration if they occur in a small region. If they occur throughout a large region, their impact is ambiguous and could relieve environmental pressure on existing cultivated area. Extension of transportation infrastructure at the edge of cultivation has somewhat different effects. More environmentally degrading production techniques encourage farmers to cultivate less intensively, while improvement of environmental conditions encourages the opposite. Less effective techniques of mitigating environmental damages are used less often than more effective methods.

Research sponsored by the U.S. Department of Energy.

^aEnvironmental Sciences Division.

**[7.2.13] Estimating the Impacts, Damages, and Benefits of Fuel Cycles:
Insights from an Ongoing Study**

R. Lee

(Abstract of proceedings of the *Ottinger Conference*, Racine, Wis., September 8–11, 1992)

This paper is based on an ongoing study by Oak Ridge National Laboratory and Resources for the Future, for the U.S. Department of Energy. The study is a collaborative effort with a European research team funded by the Commission of the European Communities. Its purpose is to share some insights from the ongoing study of fuel cycle externalities. These fuel cycles involve the use of coal, biomass, oil, hydro, natural gas, uranium, wind, and photovoltaic sources to generate electric power. The Damage Function Approach is used to identify the stages of each fuel cycle; to estimate the emissions and other

residuals from each stage and their impacts on ecological, human, and social resources; the economic values of those impacts; and the externalities, which are damages and benefits of the fuel cycle not reflected in the price of electricity. Experience gained in the study suggests that no single generic value exists for the externalities of any fuel cycle. Externalities are generally project- and site-specific. An externalities tax is suggested as an approach to internalize externalities.

Research sponsored by the U.S. Department of Energy.

**[7.2.14] Environmental Emissions and Socioeconomic Considerations
in the Production, Storage, and Transportation of
Biomass Energy Feedstocks**

R. D. Perlack
J. W. Ranney^a
L. L. Wright^a

(Abstract of ORNL/TM-12030, Oak Ridge National Laboratory, July 1992)

This report discusses an analysis conducted to identify major sources and approximate levels of emissions to land, air, and water that may result in the year 2010 from supplying biofuel conversion facilities with energy crops. Land, fuel, and chemicals are all used in the establishment, maintenance, harvest, handling, and transport of energy crops. These operations involved create soil erosion and compaction, particulate releases, air emissions from fuel use and chemical applications, and runoff or leachate. The analysis considered five different energy facility locations (each in a different major crop-growing region) and three classes of energy crops—wood crops, perennial herbaceous grasses, and an annual herbaceous crop (sorghum). All projections were based on reasonable assumptions regarding probable species used, type of land used, equipment requirements, chemical input requirements, and transportation fuel types. Emissions were summarized by location and class of energy crop. Soil loss resulting from wind and water erosion was the largest output, in tons of material, for all crop types at all locations. The relationship of soil losses to allowable loss rates was not determined. Fossil-fuel CO₂ was the second-largest emission in absolute terms. Fossil-fuel CO₂ emissions from production operations were lowest (per unit of biomass energy produced) for the crops and locations with the

highest yield per acre. Handling and transportation emissions were lowest at the location where the average transportation distance was shortest. Soil carbon sequestration would offset fossil-fuel CO₂ emissions for periods of 45 to 65 years at four of the five locations. Biogenic emissions of volatile organic compounds were identified as a possibly significant emission of woody crops but were unknown for perennial grasses. This study does not compare emissions from energy crops to those that would likely occur under alternative 2010 land-use scenarios. However, the study does determine that significant amounts of land currently used for rowcrops pasture, closecrops, and hayland would likely be converted to perennial grasses and woody crops. If such land uses represent likely 2010 alternatives, changes on a landscape basis in soil loss, chemical use, and fossil-fuel emissions associated with energy crop production are likely to be small and may be beneficial. This report provides the first comprehensive summary of the types and possible levels of emissions that may be associated with the feedstock production component of biofuel commercialization. Further analysis is needed to evaluate the positive and negative environmental impacts of these emissions.

Research sponsored by the U.S. Department of Energy.

^aEnvironmental Sciences Division.

[7.2.15] Identification of Defense-Related Industrial Firms with Significant Energy Demand in Selected States

Sterling Hobe Corporation
D. J. Bjornstad

(Abstract of ORNL/M-1831, Oak Ridge National Laboratory, April 1991)

The objective of this study is to identify those defense-related firms that may require U.S. Department of Energy (DOE) assistance in obtaining energy resources from the electric power industry and the petroleum and natural gas industries. DOE has identified six states containing a high concentration of such defense-related firms. These include California, Florida, Massachusetts, New York, Ohio, and Texas. This report consists of three sections. Section 1 identifies 29 defense-industry sectors that are major consumers of energy resources in the U.S. economy, without geographic designation. Section 2 identifies industrial entities in these 29 de-

fense-industry sectors in the six states. The following information is presented regarding these firms: (1) identification of the firms; (2) description of the defense-related product lines by SIC codes; and (3) location of the firm by city. An employee-based size criterion (firms with 50 or more employees) was used to screen the firms to identify significant consumers of energy. Section 3 includes listings of the target U.S. Department of Defense contractors, subdivisions, and subsidiaries.

Research sponsored by the U.S. Department of Energy Office of Energy Emergencies.

[7.2.16] Renewable Energy Data Requirements: A Review of User Opinions and Data Collection Efforts

G. G. Stevenson

(Abstract of ORNL/TM-11869, Oak Ridge National Laboratory, September 1991)

Interest in the contribution of renewable energy to the U.S. energy supply is growing. This interest stems from environmental and energy security concerns and the desire to develop domestic resources. To plan for the use of renewable energy, data are essential to a variety of users both inside and outside the government. This study identifies priorities and requirements for gathering different types of renewable energy data. Results of this study are to be used by the U.S. Department of Energy, Energy Information Administration, in planning and evaluating its ongoing and future renewable energy information programs. The types of renewable energy addressed in this study include biomass (wood,

agricultural residues, and crops grown for energy), municipal solid waste, geothermal energy, solar energy, and wind power. In summary, renewable energy data users appear to be more interested in obtaining "quantity data" (i.e., information on amounts of inputs and energy outputs from existing renewable systems) rather than price and cost information. To provide consistent, widely available renewable energy information, efforts are needed to collate data gathered under present programs, to expand the samples of and the questions contained in some surveys, and to conduct new surveys where economically feasible.

Research sponsored by the U.S. Department of Energy.

[7.2.17]**The Economics of Energy Crop Production**

A. F. Turhollow

(Abstract of Chapter 6 of *Biomass Energy Production in the U.S.: Situation and Outlook*,
U.S. Environmental Protection Agency, August 28, 1992)

This document presents a series of cost estimates for growing biomass for five combinations of major cropping strategies and region systems. Four of the systems use herbaceous energy crop technologies. The fifth is based on short-rotation woody crops. In addition to current costs (1989), this analysis projects production costs for these systems for the year 2010. Current and projected costs are compared against expected returns from traditional agricultural systems. This comparison identifies the "break-even" price per ton of biomass required for the biomass energy systems to be competitive with traditional agriculture that receives no subsidies. Because traditional agriculture, at least grains and soybeans, has negative returns without subsidies, break-even prices are lower than costs.

A number of factors influence the costs of producing dedicated biomass energy crops, including cultivation systems, species, treatments, regions, and site variability. This document ex-

amines the Midwest and South, two regions identified as having the best potential to contribute large quantities of land to the production of dedicated energy crops. The systems analyzed are: hybrid poplar, a coppicing hardwood (Midwest); sorghum, a thick-stemmed perennial (Midwest); switchgrass, a thin-stemmed perennial (Midwest); energy cane, a thick-stemmed perennial (South); and switchgrass, a thin-stemmed perennial (South). Other systems of dedicated energy crops could be considered (e.g., softwoods, thin-stemmed annuals); however, this discussion is limited to the systems outlined above because they are applicable to the vast majority of the acreage available for biomass.

Research sponsored by the U.S. Environmental Protection Agency Office of Policy, and the U.S. Department of Energy Biofuels Systems Division.

7.3 ABSTRACTS OF CENTER FOR TRANSPORTATION ANALYSIS SECTION

[7.3.1] An Airlift Capabilities Estimation Model for the Military Airlift Problem

I. K. Busch

C. Liu

M. R. Hilliard

(Abstract of pp. 136 of *Bulletin of the TIMS/ORSA Joint National Meeting*,
Orlando, Fla., April 29, 1992)

An airlift capabilities estimation model developed for the Military Airlift Command provides a quick estimate of the resources needed to achieve a desired airlift. The users are able to choose from several objective functions (e.g.,

minimize aircraft utilization, minimize shortfall) and modify resources to evaluate concepts of operation.

Research sponsored by the Military Airlift Command.

[7.3.2]

Transportation Energy Data Book: Edition 12

S. C. Davis
M. D. Morris^a

(Abstract of ORNL-6710, Oak Ridge National Laboratory, March 1992)

The *Transportation Energy Data Book: Edition 12* is a statistical compendium prepared and published by Oak Ridge National Laboratory under contract with the Office of Transportation Technologies in the U.S. Department of Energy. Designed for use as a desk-top reference, the data book represents an assembly and display of statistics and information that characterize transportation activity, and presents data on other factors that influence transportation energy use. The purpose of this document is to present relevant statistical data in the form of tables and graphs. Each of the major transportation modes—highway, air, water, rail, pipeline—is treated in separate chapters or sections. Chapter 1 compares U.S. transportation data with data from seven other countries. Aggregate energy

use and energy supply data for all modes are presented in Chapter 2. The highway mode, which accounts for more than three-fourths of total transportation energy consumption, is dealt with in Chapter 3. Topics in this chapter include automobiles, trucks, buses, fleet automobiles, federal standards, fuel economies, and vehicle emission data. Household travel behavior characteristics are displayed in Chapter 4. Chapter 5 contains information on alternative fuels and alternatively fueled vehicles. Finally, Chapter 6 covers each of the nonhighway modes: air, water, pipeline, and rail, respectively.

Research sponsored by the U.S. Department of Energy Office of Transportation Technologies.

^aUniversity of Tennessee.

[7.3.3]

Energy-Efficiency Improvement Potential of Commercial Aircraft

D. L. Greene

(Abstract of pp. 537–73 in *Annual Rev. Energy Environ.* 17, 1992)

Commercial aircraft are second only to highway vehicles as consumers of motor fuels, and demand for air travel is growing nearly twice as fast as demand for travel by highway vehicles. Since the early 1970s, air transport has doubled its energy efficiency by means of improved technology and operations. This article covers

commercial aircraft energy use and efficiency for the period 1970–1989; technological potential to improve commercial aircraft energy-efficiency; commercial aircraft efficiency estimates; and projected stock efficiency improvements.

Research sponsored by the U.S. Department of Energy.

[7.3.4]

Vehicle Use and Fuel Economy: How Big Is the "Rebound" Effect?

D. L. Greene

[Abstract of *The Energy Journal* 13(1), 1992]

By reducing the fuel costs of travel, motor vehicle efficiency improvements tend to increase the demand for travel, thereby offsetting some of the energy-saving benefit of the efficiency improvement and creating a "rebound" effect.

The key factor is the elasticity of vehicle travel with respect to fuel cost per mile. Past studies offer a wide range of estimates depending on model formulation and time period, with more recent analyses indicating that travel is insensi-

tive to fuel costs and efficiency. This paper analyzes U.S. light-duty vehicle miles traveled from 1966–89, examining a variety of statistical issues that bear on the size of the “rebound” effect, including error structure, functional form, and possible lagged effects. The results consistently confirm that the “rebound” effect has been quite small, about 5 to 15%, or less, and that short-run (one year) adjustments accounted for

essentially all of the change in travel due to fuel price and fuel economy changes. The findings imply that the energy savings of technical fuel economy improvements to cars and light trucks will be only slightly reduced by increased vehicle travel. They also imply that gasoline taxes would need to be very large to stimulate significant reductions in travel.

Research sponsored by the U.S. Department of Energy.

[7.3.5] Costs and Benefits of Automotive Fuel Economy Improvement: A Partial Analysis

D. L. Greene
K. G. Duleep^a

(Abstract of ORNL-6704, Oak Ridge National Laboratory, April 1992)

This report describes an exercise in estimating the costs and benefits of technology-based fuel economy improvements for automobiles and light trucks. Benefits quantified include vehicle costs, fuel savings, consumers' surplus effects, the effect of reduced weight on vehicle safety, impacts on emissions of CO₂ and criteria pollutants, world oil market and energy security benefits, and the transfer of wealth from U.S. consumers to oil producers. A vehicle stock model is used to capture sales, scrappage, and vehicle-use effects under three fuel price scenarios. Three alternative fuel economy levels for the year 2001 are considered, ranging from 32.9 to 36.5 miles per gallon (mpg) for cars and 24.2 to 27.5 mpg for light trucks. Overall, fuel economy improvements of this size are probably cost-effective. The size of the benefit, and even whether there is a benefit, strongly depends on the financial costs of fuel economy improvement and judgments about the values of energy security, emissions, safety, etc. Three sets of values for eight parameters are used to define the sensitivity of costs and benefits to key assump-

tions. The net present social value (1989 dollars) of costs and benefits ranges from a cost of \$11 billion to a benefit of \$286 billion. The critical parameters are the discount rate (10% vs 3%) and the values attached to externalities. The two largest components are always the direct vehicle costs and fuel savings, but these tend to counterbalance each other for the fuel economy levels examined here. Other major components are the wealth transfer, oil cost savings, CO₂ emissions reductions, and energy security benefits. Safety can impact emissions of criteria pollutants, and consumers' surplus effects are relatively minor components. The critical issues for automotive fuel economy are therefore: (1) the value of present vs future costs and benefits, (2) the values of external costs and benefits, and (3) the financially cost-effective level of mpg achievable by available technology.

Research sponsored by the U.S. Department of Energy Office of Energy Demand Policy.

^aEnergy and Environmental Analysis, Inc.

[7.3.6] Motor Fuel Economy: The Forgotten HC Control Strategy?

D. L. Greene
M. A. Deluchi^a
Q. Wang^a

(Abstract of ORNL-6715, Oak Ridge National Laboratory, June 1992)

Emissions of hydrocarbons (HCs) from motor vehicles are major contributors to ozone pollution in urban areas. Petroleum-based motor fuels contain volatile organic compounds (VOCs) that, together with nitrogen oxides, promote the formation of ozone in the troposphere via complex photochemical reactions. VOC emissions from the tailpipe and evaporation from the fuel and engine systems of highway vehicles are believed to account for about 40% of total VOC emissions in any region. But motor fuels also generate emissions throughout the fuel cycle, from crude oil production to refining, storage, transportation, and handling, that can make significant contributions to the total inventory of VOC emissions. Many of these emission sources are directly related to the quantity of fuel pro-

duced and handled throughout the fuel cycle. Therefore, a reduction in total fuel throughput might reasonably result in a reduction of VOC emissions. In particular, reducing vehicle fuel consumption by increasing vehicle fuel economy should reduce total fuel throughput, thereby cutting total emissions of VOCs. This report identifies and quantifies to the extent possible the sources of VOC emissions throughout the motor fuel cycle and describes their dependence on automobile and light truck fuel economy.

Research sponsored by the U.S. Department of Energy Office of Environmental Analysis.

^aUniversity of California at Davis.

[7.3.7] TIGER5—Extraction of Geographic Information from the TIGER System

R. K. Gryder

(Abstract of ORNL/TM-12061, Oak Ridge National Laboratory, May 1992)

The need for geographic information in digital form is becoming apparent in many areas, including Emergency Response Planning and Management. The Census Bureau recognized this need and developed an automated geographic data base, known as the Topologically Integrated Geographic Encoding and Referencing (TIGER) System, to produce the geographic products for the 1990 census. The Bureau makes this information publicly available on CD-ROM disks. As distributed, the geographic information is not directly visible, and a program is needed to display the information in a graphic form. MapInfo is a commercially available program that can display maps and allow

the user to perform certain geographic analyses. MapInfo runs on a variety of low-cost platforms that may be found in an average office environment, as well as on high-performance work stations. The TIGER5 program developed by the Emergency Management Information Systems (EMIS) project at Oak Ridge National Laboratory reads files directly from the Census Bureau TIGER/Line CD-ROM and creates MapInfo Exchange Format Files that can be directly imported into MapInfo. The standard default values for scaling parameters are used, and the resulting map is in the same coordinate system as the world and state maps distributed with MapInfo.

Research sponsored by the U.S. Department of the Army.

[7.3.8]**Survey of Data Compression Techniques**

R. Gryder
K. A. Hake

(Abstract of ORNL/TM-11797, Oak Ridge National Laboratory, November 1991)

The Assistant Secretary of the Army for Research, Development, and Acquisition has assigned to the Project Manager, Acquisition Information Management (PM-AIM), program management responsibilities for development of the Army Acquisition Management System, including the development of the Acquisition Information Management Network (AIMNET), a secure classified network. PM-AIM also has oversight of the Army Material Plan Modernization (AMPMOD) secure telecommunications network. The AIM project plans require assessment of the current capabilities of AIMNET, the AMPMOD Network, the development of plans for transition of these to the Defense Data network (DDN) Defense Secure Network 1 (DSNET1, where the 1 refers to Secret level), the deployment of an AIM

Program Manager Information System, a Project Manager-Program Executive Officer AIMNET workstation that will run the Program Manager Support System software, and the development of plans for and analysis of telecommunications and hardware-software system enhancements, including tests of alternative enhancements. PM-AIM has requested the U.S. Department of Energy (DOE) to provide assistance in researching the feasibility of using data compression techniques to improve transfer efficiency over both the dedicated and DDN networks. DOE asked Martin Marietta Energy Systems, Inc., a prime contractor, to provide the required assistance to PM-AIM. This paper reports the status of Task 2B of the Statement of Work.

Research sponsored by the U.S. Department of the Army.

[7.3.9]**Preliminary Assessment of Future Refining Impacts of the Clean Air Act Amendments of 1990**

G. R. Hadder

(Abstract of ORNL-6688, Oak Ridge National Laboratory, November 1991)

A preliminary assessment of the future refining impacts of the Clean Air Act Amendments of 1990 has been performed with the Navy Mobility Fuels Forecasting System. The assessment suggests that gasoline-reformulation costs in domestic coastal and near-coastal refining regions in the year 2000 could be 3.5 to 5.6 cents per gallon (in 1989 currency). For heating value equivalent to one gallon of conventional gasoline, the regional total added costs (including reformulation costs) for reformulated gasoline could be 5.9 to 8.0 cents. In blending reformulated gaso-

lines, the reduction of butane for lower Reid vapor pressure and the reduction of reformate for lower aromatics are generally compensated by increased percentages of alkylate or straight-run naphthas. Relatively larger refinery process capacity additions are required for butane isomerization, alkylation, aromatics recovery, and distillate hydrotreating.

Research sponsored by the U.S. Department of Energy Office of Energy Demand Policy and the U.S. Department of the Navy, Navy Energy and Natural Resources Office.

[7.3.10] Information Survey for Microcomputer Systems Integration

K. A. Hake

(Abstract of ORNL/TM-11934, Oak Ridge National Laboratory, November 1991)

One goal of the Project Manager, Acquisition Information Management (PM-AIM) is to provide U.S. Army Project Managers (PMs) and Project Executive Officers (PEOs) with a fundamental microcomputing resource to help perform acquisition information management and its concomitant reporting requirements. Providing key PMs and PEOs with a microcomputer-based workstation configured with appropriate application software represents one means of accomplishing this goal. The workstation would furnish a broad range of capabilities needed in the PM and PEO office settings and software tools for specific

project management and acquisition information. Although still in the conceptual phase, the practical result of this exercise in systems integration will likely be a system called the Project Manager's Information System or the AIM workstation. It would include such software as Project Manager's System Software, Defense Acquisition Executive Summary, and Consolidated Acquisition Reporting System, and would conform to open systems architecture as accepted by the U.S. Department of Defense.

Research sponsored by the U.S. Department of the Army.

[7.3.11] Utility FGD Survey: January-December 1989

S. L. Hance^a
R. S. McKibben^a
F. M. Jones^a

(Abstract of project summary, ORNL/M-2347, Oak Ridge National Laboratory, March 1992)

The flue gas desulfurization (FGD) survey report is prepared annually by International Technology (IT) Corporation (formerly PEI Associates, Inc.) for the U.S. Department of Energy. The current issue and preceding issues (from 1974 to 1981 and October 1984 to the present) of the *Utility FGD Survey* are available only through the National Technical Information Service (NTIS). Preceding issues covering January 1982 through September 1984 may be purchased from the Research Reports Center of the Electric Power Research Institute. The information in this report is generated by a computerized data base system known as the Flue Gas Desulfurization Information System (FGDIS). The design information contained in the FGDIS encompasses the entire emission-control system and the power-generating unit to which it is applied. Performance

data for operational FGD systems include monthly dependability parameters, service time, and descriptions of operational problems and solutions. This report summarizes the status of FGD technology as of December 1989. It highlights the status of the electric utility power industry, projected growth of coal-fired power generation, and the current status and future trends in FGD application. Also discussed is the status of FGD technology used by nonutility generators that sell or are projected to sell electric energy or capacity (or both) to electric utilities.

Research sponsored by the U.S. Department of Energy Office of Environmental Analysis.

^aIT Corporation.

**[7.3.12] Scheduling the Operation Desert Storm Airlift: An Advanced
Scheduling Support System**

M. R. Hilliard	I. G. Harrison
R. D. Kraemer	C. Liu
R. S. Solanki	I. K. Busch

(Abstract of pp. 131–146 in *Interfaces*, January-February 1992)

A typical airlift mission carrying troops and cargo to the Persian Gulf required a three-day round trip, visited seven or more airfields, burned almost one million pounds of fuel, and cost \$280,000. During Operation Desert Storm, the Military Airlift Command (MAC) averaged more than 100 such missions daily as it managed the largest airlift in history. By August 7, 1991, more than 25,000 missions had moved more than 966,000 passengers and 774,000 tons of cargo to and from the Persian Gulf region. Each mission required scheduling aircraft, crew, and mission support resources to maximize the on-time de-

livery of cargo and passengers. To meet this challenge, MAC worked with the Oak Ridge National Laboratory to develop and deploy the AMC Deployment Analysis System (ADANS). Within three months, ADANS provided a set of decision support tools to manage information on cargo and passengers to be moved and the available resources, as well as tools to schedule missions, to analyze the schedule, and to distribute the schedule to MAC's worldwide command and control system.

Research sponsored by the Military Airlift Command.

**[7.3.13] An Interactive Analysis Tool for the Military Airlift
Scheduling Algorithm**

C. Liu
I. K. Busch
G. Harrison

(Abstract of pp. 136 of *Bulletin of the TIMS/ORSA Joint National Meeting*, Orlando, Fla., April 29, 1992)

We have developed an analysis tool that interacts with a dynamic programming-based scheduling algorithm. Due to the amount of data and number of constraints interacting with one an-

other, the decisions made by the model are often obscure. The analysis tool is used to diagnose the behavior of the model.

Research sponsored by the Military Airlift Command.

**[7.3.14] Fleet Vehicles in the United States: Composition, Operating
Characteristics, and Fueling Practices**

S. P. Miaou
P. S. Hu
J. R. Young^a

(Abstract of ORNL-6717, Oak Ridge National Laboratory, June 1992)

As fleets become a larger proportion of the new vehicle population on the road, they have more

influence on the characteristics of the total U.S. motor vehicle population. One of the charac-

teristics that fleets are expected to have the most influence on is the overall vehicle fuel economy. Because of the relatively large market share and the high turnover rate of fleet vehicles, fleets have been considered as a useful initial market for alternative-fuel vehicles. Information is essential on fleet sizes and composition, fleet vehicle operating characteristics (such as daily/annual miles of travel), fuel efficiency, and refueling practices in order to analyze fleet market potential and likely market penetration of alternative-fuel vehicles and to assess infrastructure requirements for successful operations of these vehicles in the future. This report gathers and summarizes information from the latest data

resources available pertaining to fleet vehicles in the United States and presents fleet vehicle data on composition, operating characteristics, and fueling practices. Questions these data are intended to address include: (1) How are fleet vehicles operated? (2) Where are they located? and (3) What are their usual fueling practices? Because a limited number of alternative-fuel fleet vehicles are already in use, data on these vehicles are also included in this report.

Research sponsored by the U.S. Department of Energy Office of Transportation Technologies and Office of Policy, Planning, and Analysis.

^aUniversity of Tennessee.

[7.3.15] A Macro Level Analysis of the Airlift Deployment Problem

A. K. Rath
R. S. Solanki
R. L. Church^a

[Abstract of pp. 731-42 in *Computers and Operations Research: An International Journal* 19(8), 1992]

This paper presents mathematical models for a macro-level analysis of the aircraft deployment problem that involves the allocation of a limited number of aircraft towards the shipment of cargo and personnel between many origins and destinations within prescribed time windows. The problem has been modeled by three linear programming formulations so that it can be quickly solved in a PC environment. The first and second formulations represent an explicit statement of the problem. These formulations attempt to optimally allocate strategic airlift resources towards the shipment of demand (cargo and personnel) so that the maximum amount of demand is

delivered on time using preferred aircraft types. A smaller statement of the problem is achieved in the third formulation by assuming that lateness is distributed evenly over all routes. Thus, the formulations offer a trade-off between the degree of control to be exercised by the planner and the speed of computation. This paper presents the basic structure of these formulations along with some test results.

Research sponsored by the U.S. Department of Defense, U.S. Transportation Command.

^aDepartment of Geography, University of California, Santa Barbara.

[7.3.16] A Software Utility for Regional Evacuation (SURE)

A. K. Rath
M. M. Venigalla^a

(Abstract of Proceedings, *8th National Conference on Computing in Civil Engineering*, Dallas, June 7-9, 1992)

Regional evacuation is often a viable safeguard against natural catastrophes such as hurricanes

and volcanic eruptions, as well as man-made disasters such as toxic gas release into the atmos-

phere. Several computer programs exist for modeling regional evacuation on a given road network. As expected, these models are data intensive. This paper discusses the development of a PC-based interactive computer model, Software Utility for Regional Evacuation (SURE), to create input to IDYNEV (for Interactive Dynamic EVacuation model) and analyze its output. The pre-processor module of SURE substantially reduces the time required to create

input files to IDYNEV, and the post-processor module summarizes the simulated results from the usually huge IDYNEV output files. The model also graphically illustrates the evacuation network and highlights problem links and intersections at selected intervals.

Research sponsored by the U.S. Department of Transportation, Federal Highway Administration.

^aUniversity of Tennessee.

[7.3.17] Expert Systems and the CPI Product Substitution Review: A Needs Analysis for the U.S. Bureau of Labor Statistics

B. E. Tonn
L. F. Arrowood^a

(Abstract of ORNL/TM-11987, Oak Ridge National Laboratory, February 1992)

This report presents recommendations relative to the use of expert systems and machine learning techniques by the Bureau of Labor Statistics (BLS) to substantially automate product-substitution decisions associated with the Consumer Price Index (CPI). Thirteen commercially available, PC-based expert system shells have received in-depth evaluations. Various machine learning techniques were also reviewed. Two recommendations are given: (1) BLS should use the expert system shell LEVEL5 OBJECT and

establish a software development methodology for expert systems; and (2) BLS should undertake a small study to evaluate the potential of machine learning techniques to create and maintain the approximately 350 ELI-specific knowledge bases to be used in CPI product-substitution review.

Research sponsored by the U.S. Bureau of Labor Statistics.

^aComputing and Telecommunications Division.

[7.3.18] A Shared Data Environment for the Military Traffic Management Command Directorate of International Traffic

L. F. Truett
D. L. Russell^a
V. V. Wheeler^a

(Abstract of ORNL/TM-12042, Oak Ridge National Laboratory, January 1992)

In September 1991, researchers at Oak Ridge National Laboratory (ORNL) completed a task to assist the Military Traffic Management Command Directorate of International Traffic (MTIT) in analyzing a potential Shared Data Environment (SDE) for MTIT automated cargo traffic systems. This analysis was a preliminary effort with emphasis on documentation of requirements, ex-

amination of design alternatives, and identification of specific MTIT systems' data-sharing problems. This report records the results of the ORNL analysis. The SDE envisioned by ORNL at this point in the analysis is not merely a repository of information; it is also a system that allows processing of distributed data. To provide high-level access to and control over international

cargo processes, ORNL recommends a loosely coupled, replicated data base design with high-speed communications among all sites.

Research sponsored by the U.S. Department of Defense Military Traffic Management Command.

^aUniversity of Tennessee.

[7.3.19]

Quality Assurance Review of Manual and Automated Data Handling Procedures: Annual Nonutility Power Producer Report: Form EIA-867

L. F. Truett

(Abstract of ORNL/Sub/87-SB595/16, Oak Ridge National Laboratory, October 1991)

The post-implementation review of the Annual Nonutility Power Producer Report, Form EIA-867, survey system was conducted for the following purposes: (1) to determine whether the system's manual and automated procedures collect and process data in a manner that ensures data reliability and produces accurate and timely information; (2) to ensure that the system documentation accurately describes the data collection and processing procedures; and (3) to evaluate the extent of the system's compliance with current applicable Energy Information Administration (EIA) standards.

To accomplish these objectives, the audit team adopted a three-level hierarchical approach to the system review. Level I consisted of a review of the appropriate system documentation and the overall system flow. Level II consisted of a review of system operations and an analysis of the system software and the processing of various types of data records. Level III evaluated the effects of the system's automated edits and identified audit trails and quality-control checkpoints. The Form EIA-867 survey is a mandatory annual survey that collects data from approximately 1500 respondents pertaining to the generation capacity and sale of electricity by

nonutility power producers. The form is divided into four schedules and collects data from a census of nonutility facilities with a total generating capacity of 1 MW or more. The audit team identified those EIA standards that apply to the Form EIA-867 system and that fell within the scope of the review. The evaluation revealed that in most respects the system complied with the relevant standards. The audit team also found that system operations were effective in producing accurate and reliable results. The Form EIA-867 survey has collected only two years of data. The first publication of the Form EIA-867 data will appear in the *Electric Power Annual*. The information included in the documentation of manual and automated procedures is accurate and complete. The automated system generally is effective and well controlled. All edits are performed as expected, and error messages are generated accordingly. In general, therefore, the audit team judged the Form EIA-867 survey system to be operating effectively.

Research sponsored by the U.S. Department of Energy, Energy Information Administration.

7.4 ABSTRACTS OF EFFICIENCY AND RENEWABLES RESEARCH SECTION

[7.4.1] Experimental Investigation of Steep-Front Short-Duration (SFSD) Surge Effects on Power Systems Components

R. Barnes
D. B. Miller^a

(Abstract of ORNL/Sub/87-91345, Oak Ridge National Laboratory, May 1992)

This report presents results from experiments in which steep-front, short-duration (SFSD) voltage impulses were imposed on various electrical power distribution components. These pulses were generated by switching a section of charged, high-voltage coaxial cable across the component under study. Components included underground distribution cable, cable terminators, insulators, and arresters. SFSD voltage needed to flashover 15-kV polyethylene cable with a single pulse is approximately 625-kV peak. Strength of polyethylene cable decreases with increasing number of SFSD pulses, indicating cumulative degradation of the polymer. For 15-kV and 25-kV cable terminators, the SFSD

CFO was over twice the rated standard lightning basic impulse level for the same units. Similarly, porcelain suspension insulators required more than a doubling of voltage to decrease time to flashover from 1 microsecond to 0.1 microsecond. Arresters were found to respond rapidly to steep-front current pulses, but the arrester material itself was found to result in a higher discharge voltage for SFSD pulses. Arresters also showed a delay in turn-on of current following the arrival of a steep-front voltage surge.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aMississippi State University.

[7.4.2] Mitigation of Magnetohydrodynamic Electromagnetic Pulse (MHD-EMP) Effects in Commercial Electric Power Systems

R. P. Barnes
F. M. Tesche^a
E. F. Vance^b

(Abstract of ORNL/6709, Oak Ridge National Laboratory, March 1992)

A large nuclear detonation at altitudes of several hundred kilometers distorts the earth's magnetic field and produces a strong magnetohydrodynamic electromagnetic pulse (MHD-EMP) that can adversely affect electrical power systems. This report considers the effects of this nuclear environment on critical facilities connected to the commercial power system. Methods of mitigating the MHD-EMP impacts are investigated,

and recommended protection schemes are presented. The report also discusses guidelines for testing facilities to determine the effects of MHD-EMP and to validate the mitigation methods.

Research sponsored by the U.S. Department of Energy Office of Energy Management, and the Defense Nuclear Agency.

^aConsultant, Dallas.

^bConsultant, Fort Worth, Texas.

[7.4.3] Magnetohydrodynamic Electromagnetic Pulse (MHD-EMP) Interaction with Power Transmission and Distribution Systems

P. R. Barnes
F. M. Tesche^a
A. P. Sakis Meliopoulos^b

(Abstract of ORNL/Sub/90-SG828/1, Oak Ridge National Laboratory, February 1992)

This report discusses the effects of the late-time high-altitude electromagnetic pulse on electrical transmission and distribution systems. This environment, known as the magnetohydrodynamic electromagnetic pulse (MHD-EMP), is a very slowly varying electric field induced in the earth's surface, similar to the field induced by a geomagnetic storm. It can result in the flow of a quasi-dc current in grounded power lines and in the subsequent magnetic saturation of transformers. This saturation, in turn, causes 60-Hz harmonic distortion and an increase in the reactive power required by generation facilities. This report analyzes and discusses these phenomena. The MHD-EMP environment is briefly discussed,

and a simplified form of the earth-induced electric field is developed for use in a parametric study of transmission-line responses. Various field-coupling models are described, and calculated results for the responses of both transmission- and distribution-class power lines are presented. These calculated responses are compared with measurements of transformer operation under dc excitation to infer the MHD-EMP response of these power-system components.

Research sponsored by the U.S. Department of Energy Office of Energy Management, and the Defense Nuclear Agency.

^aElectromagnetics Consultant.

^bGeorgia Institute of Technology.

[7.4.4] Future Directions: Integrated Resource Planning

D. C. Bauer
J. H. Eto^a

(Abstract of *Achieving Technical Potential: Programs That Work*, Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, Asilomar Conference Center, Pacific Grove, Calif., August 30–September 5, 1992)

Integrated resource planning (IRP) is the process for integrating supply- and demand-side resources to provide energy services at a cost that balances the interests of all stakeholders. Currently, IRP is the resource planning process used by electric utilities in more than 30 states. The goals of IRP have evolved from least-cost planning and encouragement of demand-side management to broader, more complex issues, including core competitive business activity, risk management and sharing, accounting for externalities, and fuel switching between gas and electricity. IRP processes are being extended to

other interior regions of the country, to noninvestor owned utilities, to regional (rather than individual utility) planning bases, and to other fuels (natural gas). This paper suggests ways the comprehensive, multi-valued, and public reasoning characteristics of IRP could be extended to applications beyond energy, such as transportation, surface water management, and health care.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aLawrence Berkeley Laboratory.

[7.4.5] Alternatives to CFC Refrigerants for Refrigerators and Other Refrigeration Systems

V. D. Baxter

(Abstract of *Proceedings of WATtec 1992*, Knoxville, Tenn., February 20, 1992)

This presentation discussed recent work at Oak Ridge National Laboratory on analysis and testing of alternative refrigerants for a number of different refrigeration end uses. End-use applications covered include household refrigerators, commercial refrigeration, and centrifugal chillers. The predominant refrigerant currently used in refrigerators is R-12. Three pure fluid alternatives (R-134, R-134a, R-152a) have been tested in standard refrigerators with compressors tailored to each alternative. Results showed higher energy consumption than with R-12 by 3% to 5%. Several two-evaporator refrigerator designs tested with pure fluid and mixture alternatives have shown energy-use reductions of 3% to 6% over standard refrigerators with R-12. Extensive analytical screenings of alternative re-

frigerants for commercial (supermarket) refrigeration and centrifugal chiller applications have been conducted. For supermarket systems, a number of mixtures were identified that displayed similar volumetric capacity, compression ratio, and efficiency in a low-temperature application as R-502. Most of these contained R-32, R-125, and R134a in varying amounts. A non-flammable mixture appears possible. Screening of chlorine-free alternatives to R-11 and R-123 for chillers indicates that the best performing pure fluids are flammable. However, combining these alternatives with a nonflammable fluid to produce a nonflammable mixture may be possible.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.6] Heat Pump Systems with Direct Expansion Ground Coils

V. D. Baxter

O. J. Svec^a

(Abstract of *Proceedings of the 1991 Electric Power Research Institute Conference: Meeting Customer Needs with Heat Pumps*, Dallas, October 15-18, 1991)

This paper summarizes an international research project organized within the framework of the International Energy Agency, Implementing Agreement on Heat Pumps. This cooperative project was proposed by the Canadian team and joined by the national teams of the United States of America, Japan, and Austria. The need for this research work is based on the recognition of the state-of-the-art of ground source heat pump (GSHP) technology. GSHP technology is the most successful among all renewable technologies in North America and northern Europe, but installation costs of GSHP systems are too high for worldwide penetration into the heating/cooling market. GSHP technology is important in solving global environmental problems and has the most potential for success in the renewable

technology market. Research and development should focus on lowering GSHP cost. GSHP experts believe that a solution might be to advance traditional GSHP systems, which operate on ground loops with circulating brine, into a new generation of GSHPs through further development of the direct expansion (DX) concept. Because in a DX system the brine circulation pump and the water/refrigerant heat exchanger are both eliminated, the cost of DX-GSHP systems could decrease. Potentially, the performance of DX systems will be appreciably improved. The primary objective of this project is to investigate solutions for three problems: (1) oil return from the ground loops back to the compressor; (2) efficient refrigerant flow in the entire DX system through the development of

advanced control devices; and (3) effective heat transfer between the refrigerant and the ground through the development of new ground heat-exchanger designs and better backfilling materials.

Research sponsored by the U.S. Department of Energy Office of Building Technologies, and the Electric Power Research Institute.

*Institute for Research in Construction, Ottawa, Ontario.

[7.4.7] Alternative Working Fluids for Unitary Equipment A Research Perspective

V. D. Baxter

(Abstract of *Proceedings of the EPRI Working Fluids for Unitary Air Conditioners and Heat Pumps Research Workshop*, Dallas, March 24–26, 1992)

This paper deals with current and planned Oak Ridge National Laboratory activities to characterize alternatives to R-22 for unitary heat pump and air-conditioning applications. Results of small-scale bread-board tests of potential alternatives R-32, R134a, R-152a and R-143a are discussed. Portions of the Alternative Fluorocar-

bons Environmental Acceptability Study/U.S. Department of Energy global-warming impact study dealing with the unitary application are summarized. Methods for leak detection with the new refrigerants are discussed.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.8] Evaluation of the Utilities Energy Monitoring and Control System Installed at the U.S. Army, Europe, Pirmasens and 97th Base Support Battalion, Germany

M. A. Broders
B. W. McConnell

(Abstract of ORNL/CON-334, Oak Ridge National Laboratory, January 1992)

Under the provisions of Interagency Agreement DOE No. 1938-B090-A1 between the U.S. Department of Energy and the United States Army in Europe (USAREUR), Oak Ridge National Laboratory is evaluating the utilities energy monitoring and control systems (UEMCSs) installed at USAREUR, 21st Theater Army Area Command, Pirmasens and 97th Base Support Battalion, Pirmasens, Germany. This evaluation relies upon existing data and information to examine the performance and effectiveness of these UEMCSs to determine if they are achieving their operational objectives and meeting projected energy and cost savings. The major thrusts of this report are the Husterhoeh Kaseme and the Muenchweiler Hospital Complex, the primary installations monitored and controlled by

existing UEMCSs. Significant reductions in thermal energy consumption have been achieved in Bunker Hill Village as a result of building envelope energy conservation retrofits and replacing heating systems with a UEMCS-controlled hot water district-heating system. Thermal energy consumption in Bunker Hill Village has been reduced approximately 37% over a 5-year period. The success achieved in Bunker Hill Village demonstrates the potential to save energy at other Pirmasens installations. Simple payback for the UEMCS operating in concert with the Bunker Hill Village DH system is estimated to be about 2.5 years. This report discusses and graphs the details of the evaluation.

Research sponsored by the U.S. Department of Defense.

[7.4.9] Characterization of the Weatherization Assistance Program Network

M. A. Brown

E. Michels^aM. Power^aM. J. Witherspoon^bJ. F. Eisengbert^a

(Abstract of ORNL/CON-325, Oak Ridge National Laboratory, May 1992)

This study, one of five parts of the U.S. Department of Energy's (DOE's) national evaluation of its Weatherization Assistance Program (WAP), has three major goals: (1) to enumerate the size and sources of investment in low-income weatherization; (2) to provide a count of the number of low-income units weatherized by all weatherization programs and to characterize the type and tenure of those homes; and (3) to document the extent to which the DOE/WAP funding has been expanded through use of external resources. Data on the cumulative number and characteristics of the units weatherized in five periods from Program Year (PY) 1978 through PY 1989 were collected from surveys of state WAP managers and utility conservation program managers. In addition, a national sample of 443 utilities was surveyed. This analysis considered funding only for weatherization programs targeting low-income households whose incomes did not exceed current federal standards for DOE/WAP or Low-Income Home Energy Assistance Program (LIHEAP) eligibility. Cumulative expenditures of \$4.36 billion and weatherization of 3.9 million low-income units were reported cumulatively in the 12 program years 1978–1989. Nearly 77% of all reported resources were expended by state DOE/WAP programs under DOE/WAP program regulations. In addition, utility programs for low-income households,

Source of Weatherization Program funds for program year 1978–1989.

energy conservation initiatives administered by LIHEAP, and miscellaneous state and local weatherization initiatives all provided significant resources. Significant changes in funding sources and uses over the 12-year period were identified. Differences in resources and the characteristics of programs were evident among climate regions.

Research sponsored by the U.S. Department of Energy.

^aEconomic Opportunity Research Institute.

^bNational Association for State Community Service Programs.

[7.4.10] A Status Report on the National Weatherization Evaluation

M. A. Brown

D. A. Beschen^a

(Abstract of *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Berkeley, Calif., August 30–September 5, 1992)

This poster abstract provides a status report on the national evaluation of the U.S. Department of Energy's low-income Weatherization Assis-

tance Program (WAP). In 1990, DOE initiated a national evaluation of its low-income WAP. The evaluation plan calls for three "impact" studies

and two "policy" studies to be carried out over a 3.5-year period. The three impact studies focus on the energy savings and cost-effectiveness of the program in these key WAP markets:

- single-family and small multifamily dwellings using gas or electricity for heating—the Single-Family Study;
- high-density multifamily buildings using gas, electricity, or fuel-oil for heating—the Multifamily Study; and
- fuel-oil-heated single-family homes in nine northeastern States—the Fuel-Oil Study.

The two policy studies address additional aspects of the program but are not designed to provide estimates of energy savings or cost-effectiveness. They include:

- a characterization of the WAP network, describing the weatherization practices of state and local WAP agencies, the nature of agency staff and resources, public-private partnerships, obstacles to progress, and opportunities for the future; and
- a profile of the scope of the WAP, describing low-income weatherization resources, the weatherized population, and the WAP-eligible population that remains to be served.

Each of the five studies has its own research methodology. Altogether, information is being collected from 49 States, 920 local WAP agencies, 800 utilities, and 15,000 homes.

Research sponsored by the U.S. Department of Energy

^aU.S. Department of Energy.

[7.4.11]

Spinoffs from R&D Investments

M. A. Brown

C. R. Wilson

(Abstract of *Proceedings of the 17th Annual Conference of the Technology Transfer Society*, Atlanta, June 24–26, 1992)

This paper examines spinoff benefits that result from research and development (R&D) projects and categorizes them in terms of the dimensions of market and technical newness. These dimensions are discussed with reference to two types of spinoffs: (1) alternative market applications (when the results of an R&D project are subsequently applied to a market or use that differs from the originally intended application) and (2) second-generation technologies (when the technology that was the subject of an R&D project is significantly altered or enhanced in unanticipated ways through subsequent R&D). Exam-

ples from the U.S. Department of Energy's Energy-Related Inventions Program are integrated into the results of a literature review to illustrate key concepts, including core technologies, degrees of market and technology newness, technology robustness, and the nature of connections linking spinoffs to prior R&D projects. The paper concludes by examining some of the implications presented by potential economic benefits from spinoffs for technology managers and R&D evaluators.

Research sponsored by the U.S. Department of Energy.

[7.4.12]

Demonstrations: The Missing Link In Government-Sponsored Technology Deployment

M. A. Brown

C. R. Wilson

H. C. Livesay^a

D. S. Lux^b

(Abstract from article in *Technology in Society*, July 1992)

When effectively conducted, demonstrations constitute a powerful and often essential market-

ing step for new technologies. Seven case studies illustrate the value of demonstrations to the

deployment of new energy technologies—particularly those being developed by independent inventors and small businesses. One key lesson is that successful demonstrations focus on fully qualified products. Premature prototypes, on the other hand, are more appropriate for field testing, where technical failures can be fixed without severely damaging future market prospects. A second lesson is that multiple and staged demonstrations may be necessary when industry and end-user markets are highly fragmented or when application environments are divergent. Public agencies can promote successful demonstrations in many ways: by finding suitable industrial partners and third-party monitors, by

providing subventions that lower the risks and increase economic benefits to participants, and by compiling and disseminating accurate performance data. In addition, government agencies can play a constructive role by helping technology promoters understand the distinction between field tests and demonstrations and by facilitating multiple demonstrations, when necessary.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aTexas A&M University.

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[7.4.13] Characterization of the Weatherization Assistance Program Network

M. A. Brown

M. A. Beyer^a

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W. C. Koehler, Jr.^a

(Abstract of ORNL/CON-324, Oak Ridge National Laboratory, February 1992)

The characterization of the Weatherization Assistance Program (WAP) Network was designed to describe the national network of state and local agencies that provide WAP services to qualifying low-income households. The objective of this study was to profile the current WAP network. Two national surveys were conducted: one collected data from 49 state WAP agencies, and the second collected data from 920 (or 81%) of the local WAP agencies. The specific goals of this study included collecting data for analysis of (1) the relationships between the WAP network and non-network programs and the extent of these relationships; (2) the interest and availability of potential partners for future energy-efficiency efforts; (3) the level of technical assistance, client education, and training skills;

(4) the range of experience and technical expertise for diagnosing weatherization needs and installing retrofit measures; (5) the ability of the network to provide market information on client needs and to provide feedback on the performance of new technologies; and (6) the array of innovations and cutting-edge initiatives being implemented or tested in the field. The report catalogues the total network financial support for energy programs and the total network program staff working on energy programs of both state and local WAP agencies.

Research sponsored by the U.S. Department of Energy.

^aApplied Management Sciences, Inc.

^bU.S. Department of Energy.

**[7.4.14] The Energy-Related Inventions Program: A Decade
of Commercial Progress**

M. A. Brown
C. R. Wilson^a
C. A. Franchuk

(Abstract of ORNL/CON-339, Oak Ridge National Laboratory, December 1991)

This report provides information on the recent commercial progress of inventions supported by the U.S. Department of Energy's (DOE's) Energy-Related Inventions Program (ERIP). It describes the results of the latest in a series of ERIP evaluation projects completed since 1980. It focuses on the economic impacts of the program, notably sales and employment benefits for the period of interest 1980-1990. The evaluation is based on data collected through mail and telephone surveying of 143 participants in the program. As of October 1989, a total of 486 inventions were recommended to DOE by the National Institute for Standards and Technology, which screens all submitted inventions for technical merit, potential for commercial success, and potential energy impact. By the end of 1990,

at least 109 of these inventions had entered the market, generating total cumulative sales of more than \$500 million. ERIP has generated a 20:1 return in terms of sales values to grants, and an 8:1 return in sales program appropriations. By the end of 1990, 25% of all ERIP inventions had achieved sales. Also, 23 spin-off technologies have generated sales of \$32 million. Further, an estimated 750 full-time equivalent employees were working on ERIP technologies in 1990, resulting in a return of approximately \$3.2 million in individual income taxes to the U.S. Treasury.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aUniversity of Tennessee.

**[7.4.15] A Study of Changes in Foundation Insulation
Levels in the United States**

J. E. Christian
M. K. Voss^a

(Abstract of ORNL/CON-351, Oak Ridge National Laboratory, October 1992)

For almost 10 years the U.S. Department of Energy (DOE) has sponsored a small research effort with the building industry to see that cost-effective foundation insulation levels are installed in all U.S. buildings. One of the first discoveries in 1983-1984 was that less than 5% of the existing buildings had foundation insulation and less than 30% of new construction included foundation insulation. After producing foundation handbooks, actively working with energy code and standards groups, conducting field experiments, and developing computer models for predicting energy savings, has any

measurable progress been made toward fulfilling this DOE objective? Using the network of building experts available to the Building Thermal Envelope Systems and Materials program, a short mail survey was developed, administered, and analyzed. This study concludes that foundation insulation usage on new residential buildings has increased from 1982 levels of around 25% to 1992 levels of around 50%. Government handbooks and recent changes in local enforced codes and standards are identified as major contributors to this improvement. Several issues are reported as obstacles that need to be over-

come to capture the remainder of the foundation market.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aSt. Mary's College.

[7.4.16] Roof System Effects on In Situ Thermal Performance of HCFC Polyisocyanurate Insulation

J. E. Christian
A. O. Desjarlais

G. Courville
R. Graves

(Abstract of *Proceedings of 1992 Polyurethanes Conference*, New Orleans, October 21–24, 1992)

Industry-produced, permeably faced, experimental polyisocyanurate (PIR) laminated board-stock foamed with several different hydrochlorofluorocarbons (HCFCs) is undergoing in situ testing at the Building Envelopes Research User Center at the Oak Ridge National Laboratory. The objective of this research is to determine the long-term thermal performance differences between PIR foamed with CFC-11 and PIR foamed with HCFC-123, HCFC-141b, and two blends of HCFCs. Boards from the same batch were installed in outdoor test facilities and instrumented in part to determine if the insulation thermal performance aging characteristics depend on how they are handled and installed in the field. One contribution of this research is the field validation of an accelerated thermal aging procedure. Laboratory measurements of the apparent thermal conductivity (k) of 10-mm-thick slices conducted over less than a year are

used to predict the k of 38- to 50-mm-thick PIR laminated board stock for 12 to 20 years after production. In situ thermal performance measurements of these well-characterized 3-year-old boards under white and under black ethylene propylene diene monomer (EPDM) membranes are compared with the accelerated aging procedure and with boards from the same batch in different roofing systems: mechanically attached EPDM, fully adhered EPDM, and built-up roof (BUR). The comparison indicates that this accelerated aging procedure should be seriously considered for providing in-service thermal performance information to building owners and roofing contractors.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems, Society of the Plastics Industry, Polyisocyanurate Insulation Manufacturers, National Roofing Contractors Association, and the U.S. Environmental Protection Agency.

[7.4.17] Energy-Efficient Residential Building Foundations

J. Christian

[Abstract of *ASHRAE Journal* **83**(4), November 1991]

A well-designed foundation not only is structurally sound and insulated to save energy, but also provides appropriate moisture, termite, and radon control. Reflecting increased concern for energy conservation, several national building energy codes and standards were revised in 1989–1991 to recommend foundation insulation

in climates with more than 2500 heating degree days. The importance of proper foundation insulation can be better appreciated by knowing that an uninsulated, conditioned basement may represent up to 50% of the heat loss in a tightly sealed house that is well insulated above grade. This article draws heavily from the *Builders*

Foundation Handbook published by Oak Ridge National Laboratory in May 1991.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems.

[7.4.18]

Basement and Slab Insulation Thermal Performance Field Measurements

J. E. Christian
J. Hameister^a

(Abstract of *Proceedings of the Building Thermal Envelopes V Conference*, Clearwater Beach, Fla., December 7–10, 1992)

Slab-on-grade insulation thermal performance has been constantly monitored at the Oak Ridge National Laboratory (ORNL) Roof Thermal Research Apparatus for 3 years. Hourly heat flow and temperature measurements from an extruded polystyrene insulated and uninsulated monolithic poured slab foundation wall are monitored at six locations within two instrument planes. The adjoining soil control volume is sand. Basement insulation thermal performance has been constantly monitored for 1 year at the ORNL Envelope Systems Research Apparatus. Selected hourly heat flow and temperature measurements from four solidly grouted concrete-block basement wall test sections will be compared. The adjoining soil control volume for

this facility is clay. The four basement sections are extruded polystyrene blown with HCFC-142 on the exterior, fiberglass insulation drainage board, interior framed batts, and an uninsulated wall. The results from these experiments will be presented along with comments regarding the validation of the modeling behind the *Builders Foundation Design Handbook* recommendations, CABO Model Energy Code requirements, and ASHRAE Standard 90.2P prescriptive foundation insulation recommended levels.

Research sponsored by the U.S. Department of Energy Office of Building Technology.

^aMarquette University.

[7.4.19]

Summary of a DOE Moisture Control Handbook for New, Low-Rise Residential Construction

J. Christian

(Abstract of *Proceedings of the Energy Efficient Building Association, International Conference & Exposition*, Research Triangle Park, N.C., March 4–7, 1992)

The presence of uncontrolled moisture in an envelope can rapidly degrade the thermal performance of most insulations. Less than 1% moisture content by volume in an envelope cavity can increase heat transfer by 100%. Moisture damage is the single largest factor limiting the useful life of a building: Wood decays, fasteners corrode, masonry walls leach salts, electrical wiring shorts, paint peels, siding buckles and rots, and materials discolor. Elevated levels of moisture in buildings also can lead to mold, mildew, odors, pathogens, and serious

health effects for occupants. Frequently, occupant solutions to these problems in existing buildings are energy intensive. The major motivation behind the U.S. Department of Energy's moisture research effort is to provide building designers, builders, and building owners with integrated moisture-control strategies that will contribute to the construction of long-lasting, energy-efficient buildings.

Research sponsored by the U.S. Department of Energy Office of Building Technology.

[7.4.20] Thermal Measurement of In Situ and Thin-Specimen Aging of Experimental Polyisocyanurate Roof Insulation Foamed with Alternative Blowing Agents

J. E. Christian D. L. McElroy
G. E. Courville F. J. Weaver
R. S. Graves D. W. Yarbrough
R. L. Linkous

(Abstract of *Proceedings of the American Society for Testing and Materials*, Gatlinburg, Tenn., October 1991)

This paper reports apparent thermal conductivity (k) values from field and laboratory aging tests on a set of industry-produced, experimental polyisocyanurate (PIR) laminated boardstock foamed with hydrochlorofluorocarbons (HCFCs) as alternatives to chlorofluorocarbons (CFCs). The PIR boards were blown with five gases: CFC-11, HCFC-123, HCFC-141b, and 50/50 and 65/35 blends of HCFC-123/HCFC-141b. The k-values were determined at mean temperatures from 0 to 50°C (30 to 120°F) using techniques that meet the American Society for Testing and Materials C114 and C518 test methods. Results on laminate boards with faces provide an independent laboratory check on the increase in k observed for field exposure in the Oak Ridge National Laboratory Roof Thermal Research Apparatus (RTRA). A thin-specimen

aging procedure established the long-term thermal resistance of gas-filled foams. Thin specimens were planed from the industry-produced boardstock foams and aged at 24 and 65°C for up to 300 days. Field exposures were conducted on specimens under single-ply ethylene propylene diene monomer membranes in the RTRA for more than 400 days. Hourly averages of panel temperature and heat flux were analyzed to obtain k as a function of mean temperature on a week-by-week basis. The relative performance of test specimens of HCFC-141b under a black and under a white membrane is reported.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems, Society of the Plastics Industry, Polyisocyanurate Insulation Manufacturers Association, National Roofing Contractors Association, and the U.S. Environmental Protection Agency.

[7.4.21] Thermal Mass Credits Relating to Building Envelope Energy Standard

J. Christian

[Abstract of article in *ASHRAE Transactions* 97(2), American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 1991]

The U.S. Department of Energy (DOE) supported a systematic study of the effects of exterior envelope thermal mass beginning in 1979, when there was considerable private-industry debate over the magnitude of the effect of envelope mass on annual heating and cooling loads of buildings. The result was an experimental data base consisting of thermal performance measurements on 14 test houses in two locations

with various amounts of external wall mass; detailed measurements on a massive 4,000 ft² office/dormitory; independent consistency checks on the measurements; validation of a variety of building simulation models; several extended simulated data bases of full-size, single-family residences; and several simplified techniques for predicting the effect of exterior thermal mass on annual heating and cooling

loads. This paper also briefly examines the history of the DOE Thermal Mass Research, which, in part, has led to the inclusion of Thermal Mass Credits in the Model Energy Code, 1989 edition, and ASHRAE 90.2P.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems.

[7.4.22] Thermal Performance Analysis for Heat Exchangers Having a Variable Overall Heat Transfer Coefficient

J. C. Conklin
Dr. E. Granryd^a

(Abstract of *Proceedings of the ASME Winter Annual Meeting: Heat Transfer Division Technical Program*, Atlanta, December 1-6, 1991)

The classic, conventional analysis for the thermal performance of heat exchangers is based on three assumptions: constant fluid flow rate, constant specific heat fluids, and constant overall heat transfer coefficient. This analysis describes a general approach for analyzing the thermal performance of heat exchangers in which the overall heat transfer coefficient varies as a function of enthalpy, with the other two basic assumptions of constant mass flow rates and constant specific heats unchanged. Examples are presented that illustrate the variation in overall heat transfer coefficient for an evaporation process. This paper presents a general method for computing a true area-weighted mean overall

heat transfer coefficient that permits use of a local overall heat transfer coefficient that is an arbitrary function of enthalpy. This method allows a simple yet accurate analysis to be made of the effects of a variable overall heat transfer coefficient without the use of a large mainframe computer. This report then investigates linear variation of local overall heat transfer coefficient with respect to enthalpy and two heat transfer correlations applicable to flow-boiling inside a tube.

Research sponsored by the U.S. Department of Energy.

^aRoyal Institute of Technology, Department of Applied Thermodynamics and Refrigeration, Stockholm.

[7.4.23] Thermal Conductivity of Polyisocyanurate Foam Board Insulation Blown with CFC-11 Substitutes: Laboratory and Long-Term Field Measurements

G. E. Courville
J. E. Christian
R. S. Graves^a

(Abstract of *Proceedings of the VIII Congreso Internacional de la Impermeabilizacion*, Madrid, May 20-22, 1992)

This paper reports on a series of laboratory and controlled test site measurements of the thermal conductivity of polyisocyanurate foam laminated boardstock roof insulations produced with several different blowing agents, including CFC-11, HCFC-123, HCFC-141b, and two blends of the hydrochlorofluorocarbons (HCFCs). The be-

havior of the experimental foams with HCFCs is compared to that of conventional polyisocyanurate foam blown with CFC-11. Thermal drift observed from 2 years of field exposure is compared to laboratory-accelerated aging tests, and the laboratory and field-measurement techniques are described. This work is part of a joint

industry/government project established in the United States to evaluate the technical viability of HCFC alternative blowing agents for polyisocyanurate foam roof insulations.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aMetals and Ceramics Division.

[7.4.24] Moisture Effects in Low-Slope Roofs: Drying Rates After Water Addition with Various Vapor Retarders

G. E. Courville
A. O. Desjarlais
P. W. Childs

K. E. Wilkes
C. R. Pedersen^a
T. W. Petrie^b

(Abstract of ORNL/CON-308, Oak Ridge National Laboratory, October 1992)

Tests have been conducted in the Large Scale Climate Simulator of the U.S. Department of Energy Building Envelope Research Center at the Oak Ridge National Laboratory to investigate downward drying rates of various unvented, low-slope roof systems. A secondary objective was to study heat flow patterns to understand how to control latent heat effects on impermeable heat-flux transducers. Nine test sections were tested simultaneously. Five cold-deck sections had a plywood deck above fibrous-glass insulation. They had various vapor retarder systems on a gypsum-board ceiling below the insulation. The other four warm-deck sections had a lightweight insulating concrete deck below expanded polystyrene insulation and the same vapor retarder systems. The cold-deck systems had materials relatively permeable to water vapor; the materials in warm-deck systems were less permeable. All test sections were topped by an impermeable roofing membrane. Four different vapor-retarder systems were used below the two kinds of insulation to make up eight of the test sections. Water was added to sheets of blotting paper over the insulation in these eight test sections after determining their dry steady-state and dynamic thermal characteristics. The ninth test section was of the cold-

deck type with a solid polyethylene vapor retarder, but it remained room-dry throughout. The heat-flux measurements showed that heat conduction dominates the system using impermeable insulation materials, with only a slight increase due to increased thermal conductivity of wet expanded polystyrene. There was significant transfer of latent heat in the test sections with permeable insulation, causing the peak heat fluxes to increase by as much as a factor of two. The sections without a vapor retarder dried out rapidly. Of the sections with a vapor retarder, the ones with the water-permeable vapor retarder were able to dry out all or most of the added water within a few weeks. Some water was able to escape when the vapor retarder consisted of a layer of polyethylene with punched holes. The solid polyethylene vapor retarder showed little or no drying. The water-permeable vapor retarder and the polyethylene with holes verify that downward drying is possible using the high temperatures imposed on roofs in summer.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems.

^aTechnical University of Denmark.

^bMarquette University.

**[7.4.25] Maintaining Electric Power System Performance: Preparing
for the Year 2020, Research Needs**

S. J. Dale
J. P. Stovall
K. W. Klein^a

(Abstract of ORNL-6678, Oak Ridge National Laboratory, November 1991)

The U.S. electric-power delivery system will undergo dramatic changes through the year 2020. Without an aggressive research and development (R&D) program to develop and integrate new technologies, a substantial mismatch could develop between the system's performance and public expectations of a stable, reliable source of energy. This report provides perspective on the future U.S. electrical-power delivery system and outlines the major issues for R&D support that will be required to maintain the performance of the system successfully through the year 2020. The major areas that require increased R&D attention include:

- **Effects of exposure to electric and magnetic fields (EMFs).** The issue of health effects from exposure to EMFs requires urgent consideration. The top priority should be to determine if there is a safe level of exposure to magnetic fields.
- **Real-time power system control.** Faster real-time power system controls and faster data analysis capabilities will be an absolute requirement to maintain the system stability and the high reliability of the electric supply. Important targets for research are system architecture, new modeling techniques, computers, communication and sensor technology, and information-management methods.

- **Higher-capacity transmission options.** The transmission system capability must be increased to meet the new demands and to overcome the restrictions placed on upgrading and new sitings. Important R&D issues include adequate transmission capacity, advanced transmission concepts, new materials, components, and improved maintenance.
- **High-capacity power electronics.** Power electronics will have a key role in controlling load flow, increasing transmission capacity, and facilitating integration of renewable, intermittent generation into the system. Therefore, power electronic devices with higher current and voltage ratings than are presently available must be developed. Identified areas for R&D were converter equipment for high-voltage ac/dc, interrupting equipment, and control of load flow.
- **Energy storage.** Energy storage has the potential to alleviate the need to match generation capacity with demand at all times. The total system benefit of energy storage must be determined.

Research sponsored by the U.S. Department of Energy, Assistant Secretary for Conservation and Renewable Energy, Office of Energy Management.

^aEnergetics, Inc.

[7.4.26] The Impact of Climate on the Drying Times of a Wetted Low-Sloped Roof System

A. O. Desjarlais
D. M. Kyle
J. E. Christian

(Abstract of article in *The Journal of Thermal Insulation*, September 1992)

Reroofing is expected to account for approximately 70% of 1992 contractor income. Nearly half of this total will be for recovering old roofs. This rapidly growing trend is cost-driven. Tear-off is labor intensive and expensive, disposal costs are increasing, and the economic benefit of saving existing insulation becomes a large factor as roofers more frequently encounter well-insulated roofs installed since the late 1970s. However, recovering an old roof can be risky. With no guidelines available, the decision to tear-off or recover is generally made on a case-by-case basis. The literature offers little information on this subject. Short-term laboratory tests at Oak Ridge National Laboratory (ORNL) have suggested that roof systems containing permeable insulation materials can be downwardly

dried when exposed to simulated summer conditions. The ORNL test results have been reproduced analytically using the combined heat and mass transfer model MATCH (Moisture and Temperature Calculations for Constructions of Hygroscopic Materials). A research program has been initiated at the U.S. Department of Energy Roof Research Center at ORNL to address concerns related to drying of roof systems. This paper describes one facet of this program, a series of simulations where MATCH was used to estimate drying times of a simple roof system for four different climatic regions in the continental United States.

Research sponsored by the U.S. Department of Energy Office of Building Technology.

[7.4.27] System Effects on the Thermal Aging of Experimental Polyisocyanurate Roof Insulation Foamed with an Alternative Blowing Agent

A. O. Desjarlais
J. E. Christian
R. L. Linkous

(Abstract of *Proceedings of the Building Thermal Envelope V Conference*, Clearwater Beach, Fla., December 7-10, 1992)

Experimental polyisocyanurate (PIR) foam roof insulation with 0.6-mm-thick permeable black faces blown with HCFC-141b installed on test roofs at a national laboratory for almost 3 years shows various degrees of aging. Four roof systems are being monitored to determine the effect of system type on board aging. The four systems are composed of a dry stack of insulation boards covered, respectively, by a loosely laid single-ply white membrane, a loosely laid single-ply black membrane, a built-up roof, and a fully adhered ethylene propylene diene monomer membrane. A comparison with periodic laboratory testing of

the insulation boards is also included. A data analysis program, PROPOR, has been used to estimate the thermal properties of the PIR foam insulation, to gain insight into the data and the pure conduction model used by PROPOR through sequential value and residual analyses, and to estimate the precision of the results with confidence intervals. These confidence intervals are then used to determine if the differences noted due to aging of the insulation boards contained within these systems are statistically significant. These experiments are part of a joint industry/government project established to

evaluate the technical viability of alternative HCFC blowing agents for rigid, closed-cell PIR foam roof insulations.

Research sponsored by the U.S. Department of Energy, the U.S. Environmental Protection Agency, the Society of the Plastics Industry, the Polyisocyanurate Insulation Manufacturers Association, and the National Roofing Contractors Association.

[7.4.28] Full-Scale Research Efforts in Low-Slope Roofing

A. O. Desjarlais

(Abstract of article in *Contractors Guide*, August 1992)

During the last four years, low-slope roofing systems have been subjected to a new level of scrutiny at Oak Ridge National Laboratory's Roof Research Center (RRC). These studies are adding new insights on the thermal performance of such systems and are expected to have far-reaching effects on the future of roof designs. RRC currently focuses on three low-slope roofing research activities aimed at today's uncertainties in

the marketplace. The programs involve the effects of moisture in low-slope roofs, alternative blowing agents for rigid closed-cell plastic foams, and radiation-control coatings. This report summarizes these programs, details the impact they will have on the roofing industry, and suggests future research activities.

Research sponsored by the U.S. Department of Energy Office of Buildings and Community Systems.

[7.4.29] Total Equivalent Global Warming Impact: Combining Energy and Fluorocarbon Emission Effects

P. D. Fairchild
S. K. Fischer
P. J. Hughes

(Abstract of *Proceeding of the 1991 International CFC and Halon Alternatives Conference*, Baltimore, December 4, 1991)

A study was conducted for the Alternative Fluorocarbon Environmental Acceptability Study and the U.S. Department of Energy to evaluate the global-warming impacts of chlorofluorocarbon (CFC) alternatives in refrigeration, insulation, and solvent cleaning. The concept of a total equivalent warming impact was introduced as a systems approach that accounts for direct global-warming impacts from emissions of greenhouse gases and indirect impacts due to carbon dioxide emissions resulting from energy use. The analysis focused primarily on household and commercial refrigeration, chillers and unitary air-conditioning equipment, automobile air conditioning, commercial and residential building insulation, batch and in-line general metal clean-

ing, and batch and in-line electronics cleaning in North America, Europe, and Japan. Regional differences in the uses of refrigeration and insulation were incorporated into the analysis, as well as differences in the carbon dioxide emissions from power generation resulting from variation in fuel sources (e.g., coal, hydroelectric, nuclear, natural gas). The study concludes that hydrofluorocarbon and hydrochlorofluorocarbon alternatives will dramatically reduce the direct impacts of refrigerants, blowing agents, and solvents on global warming (relative to CFCs) without significantly increasing energy use in most applications.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.30]

Global Warming and End-Use Efficiency Implications of Replacing CFCs

P. D. Fairchild
S. K. Fischer

(Abstract of *Proceedings of the 4th EPRI Conference: Meeting Customer Needs with Heat Pumps*, Dallas, October 15–19, 1991)

As a result of the international agreement to phase out chlorofluorocarbons (CFCs) because of stratospheric ozone depletion and because of the ensuing search for suitable alternatives, attention has recently increased on the *direct* global warming potential of the fluorocarbon alternatives as greenhouse gases. However, to date there has been little focus on the *indirect* global warming effect arising from end-use efficiency changes and associated CO₂ emissions. A study being conducted at Oak Ridge National Laboratory addresses this combined or total global warming impact of CFC alternatives in their major energy-related applications. This paper reviews selected results for air-conditioning, refrigeration, and heat pump applications. The

analysis indicates that the CFC-user industries have made substantial progress in approaching near-equal energy efficiency with the hydrochlorofluorocarbon (HCFC)/hydrofluorocarbon (HFC) alternative refrigerants. The findings also bring into question the relative importance of the *direct* (chemical-related) effect in many applications. Replacing CFCs is an important step in reducing the total global warming impact, and at present the HCFCs and HFCs appear to offer the best efficiency and lowest total impact of options available in the relatively short time required for the transition from CFCs.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.31]

Energy and Global Warming Impacts of CFC Alternative Technologies in HVAC Equipment

S. K. Fischer
P. D. Fairchild
P. J. Hughes

[Abstract of *IEA Heat Pump Center Newsletter* 10(3), September 1992]

Chlorofluorocarbons (CFCs) are being phased out of use rapidly to protect the ozone layer. It is important that the replacements for CFCs do not result in a net increase in global warming by introducing less efficient processes that lead to higher energy use and increased carbon dioxide emissions. A study was conducted to identify those alternative chemicals and technologies that could replace CFCs in energy-related applications before the year 2000, and to assess their total potential impact on global warming. The analysis for this project included an estimate of the direct effects from the release of blowing

agents, refrigerants, and solvents into the atmosphere and the indirect effects of carbon dioxide emissions resulting from energy use for commercial and residential building insulation, household and commercial refrigeration, building and automobile air-conditioning, and general metal and electronics solvent cleaning. The discussion focuses on aspects of the study relevant to residential and commercial space conditioning using unitary air conditioners and heat pumps and centrifugal chillers. In general, the hydrofluorocarbon and hydrochlorofluorocarbon alternatives for CFCs lead to large and sometimes

dramatic reductions in total equivalent warming impact, lifetime equivalent CO₂ emissions. Most of the reductions result from decreased direct effects without significant changes in energy use.

Research sponsored by the U.S. Department of Energy.

[7.4.32] An Analytical Screening of Alternatives for R-502 In Low-Temperature Refrigerating Applications

S. K. Fischer

[Abstract of article in *ASHRAE Transactions* 98(2), 1992]

R-502 is used as the working fluid of low-temperature refrigerating systems with evaporating temperatures as low as -40°F (-40°C). R-502 is an azeotropic blend of R-22 and R-115, and R-115 is a chlorofluorocarbon (CFC) that contributes to the destruction of stratospheric ozone. The Montreal Protocol requires a total phaseout of the production of fully halogenated CFCs, including R-115, by the year 2000. Consequently, replacement fluids will be needed for new and existing equipment. One alternative is to use R-22, but this requires major expensive design and hardware changes to keep the compressor discharge temperature below the point where the lubricant begins to break down. This study was initiated to identify other fluids that possibly could be used in either new or retrofit applications for low-temperature refrigeration. It in-

cludes an evaluation of predicted cycle efficiency, system capacity, pressure ratio, fluid flammability, and compressor discharge temperature. Eight different chemical compounds are considered for use as pure refrigerants as well as components in binary and ternary mixtures: R-134a, R-134, R-125, R-143a, R-152a, R-32, R-124, and R-22. An exhaustive study of the composition of blends was performed to determine the mass fractions of each component in the mixtures that are most promising on the basis of efficiency, flammability, low discharge temperature, and acceptable capacity and pressure ratio. Several blends are identified for further laboratory and analytical evaluation.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.33] Energy and Global Warming Impacts of CFC Alternative Technologies

S. K. Fischer

C. L. Kusik^a

P. J. Hughes

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P. D. Fairchild

E. M. McMahon^a

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(Abstract of ORNL/M-1869, Oak Ridge National Laboratory, December 1991)

The primary objective of this study is to develop representative indications of the relative energy use, associated CO₂ emissions, and total equivalent warming impact (TEWI) of chlorofluorocarbon (CFC) alternatives in their major application areas. The study was motivated by a concern that most attention to date has focused on the *direct* global warming effect of CFCs and their alterna-

tives, with inadequate attention paid to the *indirect* global warming effect of the CO₂ emissions arising from the differences in energy consumption by systems using different alternatives. *Direct* and *indirect* contributions are combined in this analysis to determine the TEWI of the various technical options. The study is international in scope and addresses CFCs and alter-

Contributions of various emissions to global warming.

natives in uses such as refrigerants, foam insulation, and metal electronic cleaning and drying processes.

Research sponsored by the U.S. Department of Energy Office of Building Technologies, and the Alternative Fluorocarbons Environmental Acceptability Study.

^aArthur D. Little, Inc.

[7.4.34] Alternative to CFCs and Global Warming: A Systems Approach to Evaluating Net Contributions to Global Warming

S. K. Fischer
M. McFarland^a

(Abstract of pp. 39–42 in *Material Research Society Bulletin*, March 1992)

Alternative chemicals and technologies are being considered as replacements for chlorofluorocarbons (CFCs). As these substitutes are being considered, attention must be given to entire "systems" instead of only to discrete quantifiable chemical properties. The potential future effect of alternative compounds on global warming is one such problem. The global warming potential of the chemical is a discrete measure of its impact on global warming. This, however, must be

considered in tandem with the efficiency and energy use of systems in which the chemical is used. In this report, two examples are illustrated and discussed to show how possibly incorrect conclusions can be drawn by ignoring system factors.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aDuPont Chemicals, E. I. DuPont de Nemours & Co.

[7.4.35] Global Warming Implications of Replacing CFCs: Combining Energy and Fluorocarbon Emission Effects

S. K. Fischer
P. D. Fairchild
P. J. Hughes

(Abstract of pp. 14–19 in *ASHRAE Journal*, April 1992)

An assessment recently conducted at Oak Ridge National Laboratory, under the joint sponsorship

of the Alternative Fluorocarbon Environmental Acceptability Study, a chemical industry consor-

tium, and the U.S. Department of Energy, addresses the combined global warming impact of options to replace chlorofluorocarbons (CFCs) in their major energy-related applications. This article introduces the concept of a total equivalent warming impact as a systems approach that accounts for the *direct* (fluorocarbon-related) and *indirect* (energy-related) impact on an application-specific basis and reviews selected results for air-conditioning, refrigeration, and heat pump applications. The analysis indicates that the CFC-user industries have made substantial progress in approaching near-equal energy effi-

ciency with the hydrochlorofluorocarbon/hydrofluorocarbon (HCFC/HFC) alternative refrigerants and foam insulation blowing agents. HCFC- and HFC-based systems are also the most feasible alternatives to replace CFCs within the current phaseout schedule. The findings also bring into question the relative importance of the *direct* effect in many refrigerant and blowing-agent applications.

Research sponsored by the U.S. Department of Energy Office of Building Technologies, and the Alternative Fluorocarbon Environmental Acceptability Study.

[7.4.36] Residential Retrofit Measure Selection Using the Weatherization Assistance Program National Energy Audit

M. B. Gettings

(Abstract of *Proceedings of the 1992 ACEEE Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Pacific Grove, Calif., August 30–September 5, 1992)

A computerized residential measure selection technique has been developed for use by the Department of Energy Weatherization Assistance Program agencies in performing energy audits on low-income building stock. The program selects cost-effective heating and cooling envelope and mechanical system measures that are applicable to each individual residence. The measure selection technique ranks all measures in order of decreasing savings-to-investment ratio (SIR), as determined by the separate application to the building described by the user. These measures are then applied in their ranked order

assuming all other measures of higher SIR have previously been installed. Thus, the effect of each measure interacting with other cost-effective measures is established. The program executes in less than a minute on most IBM-compatible machines. Data entry is accomplished through input screens where applicable options are automatically displayed during the data's required input. Default values are easily selected, and range checks are performed on values entered.

Research sponsored by the U.S. Department of Energy Weatherization Assistance Program.

[7.4.37] Comparison of Methods to Integrate DSM and Supply Resources in Electric-Utility Planning

L. J. Hill

(Abstract of ORNL/CON-341, Oak Ridge National Laboratory, December 1991)

Three methods can be used to integrate demand-side management (DSM) and supply resources in electric-utility planning: (1) a sequential approach in which DSM resources are selected first; (2) a sequential approach in which supply re-

sources are selected first; and (3) a simultaneous approach in which resources are selected jointly using some measure of cost-effectiveness as a guide. Assuming that the objective of utilities is to minimize their costs, each of the three should

theoretically result in selection of the same set of resources. This study shows that this is not the result in practice because of the difficulty in estimating the benefits of employing resources (i.e., their avoided capital and energy costs) when the two sequential approaches are used. This conclusion is based on comparing the simulation results of resource selection by a hypothetical utility using the three integrating methods under different operating conditions.

These simulation results suggest that, if a utility's goal is to find the resource mix that minimizes its cost, it should use the simultaneous integrating method. The reason is that the simultaneous method allows for more interaction between the characteristics of resources, both between supply and DSM resources and over time.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

Summary of simulation results
(Amounts in millions of 1991 dollars)

Integrating method	Net present value (NPV) of plan costs assuming peak demand growth of ^a —			% Incremental resources due to DSM in year ^b —	
	1%	2%	3%	2000	2010
Sequential demand ^c	1,330	1,542	1,788	51.5	43.4
Sequential supply ^d	1,330	1,528	1,788	100.0	60.9
Simultaneous	1,322	1,527	1,779	100.0	77.8

^aThe small differences in values among the costs of integrating methods are an artifact of the assumptions underlying their calculation. The assumptions include 1,000 MW of peak load in the base year and no real growth in fuel prices and capital costs for supply resources. If fuel prices are assumed to increase at growth rates projected by the Energy Information Administration, for example, the NPV of plan costs for the sequential supply and simultaneous methods under the two percent load growth scenario are \$1,994 million and \$1,975 million, respectively.

^bBased on 2% peak demand growth. Total incremental resources are the resources added to those existing in the base year to satisfy assumed peak demand growth. The percentage accounted for by DSM programs is the ratio of new DSM programs added to satisfy load growth to the incremental total.

^cThe sequential integrating method with DSM resources selected first.

^dThe sequential integrating method with supply resources selected first.

[7.4.38] The Effects of Utility DSM Programs on Electricity Costs and Prices

E. Hirst

(Abstract of ORNL/CON-340, Oak Ridge National Laboratory, November 1991)

More and more U.S. utilities are running larger demand-side management (DSM) programs. Assessing the cost-effectiveness of these programs raises difficult questions for utilities and their regulators. This study offers quantitative estimates on the trade-offs between total costs and electricity prices. This study uses a dynamic model to assess the effects of energy-efficiency programs on utility revenues, total resource costs, electricity prices, and electricity consumption for the period 1990 to 2010. These DSM

programs are assessed under alternative scenarios; factors include fossil-fuel prices, load growth, the amount of excess capacity the utility has in 1990, planned retirements of power plants, the financial treatment of DSM programs, and the costs of energy-efficiency programs. The analyses are conducted for three utilities: a "base" typical of U.S. utilities; a "surplus" utility that has excess capacity, few planned retirements, and slow growth in fossil-fuel prices and incomes; and a "deficit" utility that has little

excess capacity, many planned retirements, and rapid growth in fossil-fuel prices and incomes. The figure illustrates key findings from these simulations. They are as follows:

- In general, DSM programs reduce electricity costs and raise electricity prices. Utilities and regulatory commissions must make trade-offs between the total-resource-cost test and the rate-impact measure.
- Typically, the percentage reduction in electricity cost is much greater than the percentage increase in electricity price caused by DSM programs.
- The financial treatment of DSM programs matters. Expensing DSM program costs reduces program benefits by raising electricity prices in the short term. Capitalizing these costs defers the price increase for several years and reduces its size.
- Even if DSM is inexpensive or the utility faces high avoided costs, the trade-off between costs and prices remains. In special cases where the cost per kWh of DSM programs is quite low, both prices and costs can be reduced.
- From the perspective of costs, DSM programs are cost effective even if the utility has excess capacity and slow load growth. This occurs because DSM programs offset not just operating costs of existing plants, but also reduce the other costs of operating the utility system, defer construction of new transmission and distribution facilities, and, in the long term, defer the construction and operation of new power plants.

- The size of the trade-off between costs and prices can be reduced by having customers share in the costs of the installed DSM measures, by reducing the maximum cost of conserved electricity paid by the utility, or by delaying implementation of the program. However, these approaches also reduce the savings achieved by the programs, increasing the need for additional power supplies. Utilities and regulators should adopt a flexible approach in assessing DSM programs. Rather than strictly adhering to any single measure of cost effectiveness, they should work together to change program design and timing so that DSM programs provide major reductions in electric-energy-service costs with only minor increases in electricity prices.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

The effects of utility DSM programs on the net present value of utility revenues and average electricity price (1990-2010) for the base, surplus, and deficit utilities.

[7.4.39]

Effects of Utility DSM Programs on Risk

E. Hirst

(Abstract of ORNL/CON-346, Oak Ridge National Laboratory, May 1992)

Electric utilities face a variety of uncertainties that complicate their long-term resource planning and acquisition. As utilities increasingly turn to demand-side management (DSM) programs to provide energy and capacity resources, it becomes more important to analyze the inter-

actions between these programs and the uncertainties facing utilities. This report uses a new planning model (DIAMOND, developed at Oak Ridge National Laboratory) to explore quantitatively the uncertainty implications of supply-only vs DSM+supply resource portfolios. The

analysis focuses on risks to society, with only limited attention to the allocation of risks among customers, shareholders, and others. Four sets of uncertainties are considered in these analyses: economic growth, fuel prices, the costs to build new power plants, and the costs to operate DSM programs. These four types of uncertainties serve as proxies for the many others that face utilities. The two types of resource portfolios are tested against these four sets of uncertainties for the period 1990–2010. Methods used include sensitivity, scenario, and worst-case analysis. Results show that it is feasible to analyze the effects on uncertainty of including DSM programs in a utility's resource mix. The sensitivity analyses show that the DSM+supply resource portfolio is less sensitive to unanticipated changes in economic growth, fuel prices, and power-plant construction costs than is the supply-only portfolio. The supply-only resource mix is better only with respect to uncertainties about the costs of DSM programs. The base-case analysis shows that including DSM programs in the

utility's resource portfolio reduces the net present value of revenue requirements by \$490 million. The scenario analysis simultaneously varies all four sets of uncertainties. These results show an additional \$30 million (6%) in benefits associated with uncertainty reduction related to these uncertainties (see figure). The worst-case analysis examines situations in which, for example, the utility plans to meet a high need for additional resources and finds out, after six years, that it actually has a low need for new resources. Here again, the DSM+supply portfolio reduces the total cost penalty associated with guessing wrong for both cases, when the utility plans for high needs and learns it has low needs (and vice versa). These and other results developed here suggest that DSM programs reduce the total-resource-cost risks that utilities face. However, DSM programs sometimes increase risks associated with electricity prices.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

Scenario analysis results showing the effects on the net present value of revenue requirements (NPV-RR) (1990–2010) and on average electricity price of changes in economic growth, fuel prices, power-plant capital costs, and demand-side management (DSM) program costs for supply-only and DSM+supply resource portfolios. The zero point for the NPV-RR is \$8.50 billion, the NPV-RR of 1990 costs. The zero point for price is 6.13 cents/kWh, the 1990 electricity price.

[7.4.40] Data and Analysis Needed to Prepare an Electric-Utility Integrated Resource Plan

E. Hirst

(Abstract of *Proceedings of the National Regulatory Research Institute: Clean Air Workshop*, St. Louis, May 7-8, 1992)

This paper discusses the importance of integrated resource planning and the key elements of such a resource plan. It is based on an Oak Ridge National Laboratory project that involved review of about 30 resource plans from utilities throughout the United States. Since completion of that project, researchers have continued to review utility plans; this paper draws primarily on the roughly 30 utility plans prepared in 1990 and 1991 that were reviewed. Where appropri-

ate, the paper explains how the Clean Air Act Amendments of 1990 affect such planning. The paper discusses the following topics: purposes of an integrated resource plan, forecasts of electricity use and peak demands, assessment of supply-and-demand alternatives, resource integration, and uncertainty analysis.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

[7.4.41] Evaluation of Utility DSM Programs

E. Hirst
J. Reed (Eds.)

(Abstract of ORNL/CON-336, Oak Ridge National Laboratory, December 1991)

This handbook on the evaluation of utility demand-side management (DSM) programs is the result of a research project cosponsored by the Integrated Resource Planning (IRP) programs of the New York State Energy Research and Development Authority and the U.S. Department of Energy. This handbook provides semitechnical guidance on how to plan and conduct evaluations and points out the pitfalls to avoid. It is written for midlevel utility staff who manage and evaluate DSM programs. It also should be valuable to users of evaluation results. Program evaluation has become a central issue in the world of utility IRP. This handbook was devel-

oped by many of those people who represent the diverse constituencies of DSM program evaluation. For example, a team was organized in New York composed of regulatory staff, environmental advocates, utility personnel, and state energy-policy planners. DSM evaluation is meaningless without attention to planning an approach, communicating results to relevant decision makers, and focusing as much on the process as on the impacts of the program. These topics are all covered in this handbook.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy, and the New York State Energy Research and Development Authority.

[7.4.42] Electric-Utility DSM Programs: 1990 Data and Forecast to 2000

E. Hirst

(Abstract of ORNL/CON-347, Oak Ridge National Laboratory, June 1992)

In April 1992, the Energy Information Administration (EIA) released data on 1989 and 1990 electric utility demand-side management (DSM)

programs. These data represent a census of U.S. utility DSM programs, with reports of utility expenditures, energy savings, and load reduc-

tions resulting from these programs. In addition, EIA published utility estimates of the costs and effects of these programs from 1991 through 2000. These data provide the first comprehensive picture of what utilities are spending and accomplishing by utility, state, and region. This

report presents, summarizes, and interprets the 1990 data and the utility forecasts of their DSM-program expenditures and impacts to the year 2000.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

[7.4.43] Electric-Utility DSM-Programs: Terminology and Reporting Formats

E. Hirst
C. Sabo^a

(Abstract of ORNL/CON-337, Oak Ridge National Laboratory, October 1991)

Utilities, their regulators, and energy policy makers need reliable information on the costs of, participation in, and energy and load effects of demand-side management (DSM) programs to make informed decisions. This handbook addresses the need for additional and better information in two ways. First, it discusses the key concepts associated with DSM program types, participation, energy and load effects, and costs. Second, the handbook offers definitions and a sample reporting form for utility DSM programs. To ensure that the discussions, reporting for-

mat, and definitions will be useful and used, development of this handbook was managed by a committee, with membership from electric utilities, state regulatory commissions, and the U.S. Department of Energy. Also, this data-collection form was pretested by seven people from six utilities, who completed the form for nine DSM programs.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy, and Electric Power Research Institute Customer Systems Division.

^aBarakat and Chamberlin, Inc.

[7.4.44] Defining and Reporting Data on Utility DSM Programs

E. Hirst
C. Sabo^a

[Abstract of pp. 635-647 in *Energy* 17(7), July 1992]

This paper discusses a new handbook that addresses the need for additional and better information about demand-side management (DSM) in two ways. First, it discusses the key concepts associated with DSM-program types, participation, energy and load effects, and costs. Second, the handbook offers definitions and a sample reporting form for utility DSM programs. The

primary purpose in developing these definitions and this form is to encourage consistency in the collection and reporting of data on DSM programs.

Research sponsored by the U.S. Department of Energy and the Electric Power Research Institute.

^aBarakat & Chamberlin, Inc.

[7.4.45] The Role of Evaluation When Electric Utilities Get Financial Incentives for Their DSM Programs

E. Hirst

[Abstract of pp. 93–107 in *Evaluation Review* 16(1), February 1992]

Electric utility demand-side management (DSM) programs affect the efficiency and timing of customer electricity use. As the number and cost of these programs increase, evaluations will become increasingly important. A key challenge is the role of evaluation in determining the amount of financial incentive that a utility earns for its DSM programs. The total benefit is the reduction in electricity use and demand multiplied by the appropriate avoided costs (energy or capacity). The net benefit is the difference between total benefit and program cost. Evaluations determine the total benefits of DSM pro-

grams. This article presents a hypothetical example of problems that might arise when evaluations are subject to litigation, a likely occurrence when utility earnings depend on evaluation results. A hypothetical illustration is used because such incentives are so new that they have yet to be tested in regulatory proceedings. This article also discusses possible resolutions to the problems raised by the hypothetical example.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

[7.4.46] Absorption Chillers: Part of the Solution

P. J. Hughes
A. J. Occhionero^a
E. A. Reid^b

(Abstract of *Proceedings of the 1991 International CFC and Halon Alternatives Conference*, Baltimore, December 4, 1991)

This report considers acid rain, ozone depletion, global warming, and implementation economics as they relate to the advisability of expanding the application of absorption chillers. Introductory and background information is provided to put the discussion in the proper context. Next, all four issues are discussed separately as they relate to absorption chillers. Acid rain, ozone depletion concerns, and implementation economics are found to support the expanded use of absorption chillers. The global-warming concern is found to be more of a gray area, but the areas of benefit correspond well with the condi-

tions of greatest economic advantage. All things considered, absorption chillers are believed to be part of the environmental and economic solution. Further, integrated resource planning processes that consider electric and gas technologies on an equal footing would come to the same conclusion for many regions of the United States.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aAmerican Gas Cooling Center.

^bColumbia Gas Distribution Company.

[7.4.47] Re-Examining Frequency Selection in Naturally Excited Homogeneous Shear Layers Using Spatio-Temporal Theory

D. M. Kyle
P. J. Strykowski

(Abstract of *Proceedings of the Free Shear Layer Instability Session at the Forty-fifth Annual Meeting of the Division of Fluid Dynamics*, Tallahassee, Fla., November 1992)

Often in real flows, natural excitation resembles a continual random process that is localized in space (i.e., at the system boundary). In a connectively unstable flow, the random pattern of shear layer waves excited in this way will grow spatially and temporally as the waves convect downstream. If power spectra at two fixed streamwise locations are used to measure the amplification rate for any given frequency, then for randomly excited flows, the measured growth rate should *not* in general be expected to match the prediction of the (monochromatic)

spatial theory. Of course, the most satisfying description of excited flows is obtained by solving the full initial/boundary value problem. Alternatively, this report shows that the historically observed discrepancies between the spatial theory and experimental observations in randomly excited, connectively unstable flows may be explained using straightforward results from spatio-temporal theory. These theoretical results are discussed along with supporting experimental data.

Research sponsored by the U.S. Department of Energy.

[7.4.48] An Automobile Heat Pump Design Model

D. M. Kyle
V. C. Mei
F. C. Chen

(Abstract of *Proceedings of the Session on Non-CFC Alternatives for Vehicle Air Conditioning*, ASHRAE Annual Meeting, Baltimore, June 1992)

A computer program has been developed to predict the steady-state performance of vapor compression automobile air conditioners and heat pumps. The code is based on the residential heat pump design model developed at the Oak Ridge National Laboratory (ORNL). The refrigeration component submodels are evaluated sequentially, starting with specified refrigerant states at certain points in the circuit. The sequence iterates as the specified refrigerant properties are updated until the solution converges. To the greatest extent possible, calculations are based on fundamental physical principles in conjunction with generalized correlations available in the research literature. A notable excep-

tion to this is the compressor submodel, which utilizes empirical performance curves for a range of compressor speeds. Heat exchanger submodels assume either finned tube or plate-fin design. These submodels calculate automatically the fraction of the heat exchanger involved with vapor, two-phase, and liquid refrigerant flow. Heat-transfer correlations and the program in general can be used with a variety of refrigerants, including R-134a. Parametric studies and validation using data obtained from ongoing laboratory experiments at ORNL are discussed.

Research sponsored by the U.S. Department of Energy Office of Transportation Technology.

[7.4.49] Market Potential Estimates and R&D Planning for Advanced Absorption Systems for Large Commercial Buildings

J. M. MacDonald
P. J. Hughes
H. A. McLain

(Abstract of *Proceedings of the 1992 ASHRAE Annual Meeting*, Baltimore, June 27–July 1, 1992)

Much effort has been spent on developing alternative technologies to reduce or stabilize electricity consumption for cooling in large commercial buildings. Among those technologies are more efficient electric-motor-driven chillers, diurnal cool storage, more efficient absorption chillers, desiccant cooling systems, and gas-fired, engine-driven chillers. A market assessment was performed to determine whether the potential benefits of a new, multi-effect absorption technology justified further research and development (R&D) to allow potential commercialization. The approach, results, and conclusions of that market assessment are presented

here. The assessment required hourly DOE-2 building loads calculations and a detailed gas/electric rate analysis for 37 cities. The results show (for a 3-year payback) that standard, direct-fired, double-effect technology could capture about 30% of the chiller market, and the advanced multi-effect technology could capture about 60%. The advanced technology yields primary energy savings, while the double-effect technology leads to negative primary energy savings.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.50] The Effects of Nonstandard Lightning Voltage Waveshapes on the Impulse Strength of Air Gaps

B. W. McConnell A. K. Mishra^a
P. Chowdhuria P. M. Martin^b

(Abstract of *Proceedings of the IEEE 1992 Winter Meeting*, Institute of Electrical and Electronic Engineers, New York, January 26–30, 1992)

Transient overvoltages caused by lightning are the most frequent cause of electrical insulation failure and the subsequent damages and outages in electrical power systems. Insulation coordination is universally based on the impulse characteristics of dielectric systems determined with a standard waveshape of the transient voltage. This internationally agreed-upon voltage waveshape is designated as the 1.2×50-ms wave, defining the time to crest as 1.2ms and the time of the subsequent decay to half value of the crest as 50ms. This specific waveshape has helped in standardizing insulation levels of power apparatus and systems. In practice, however, a dielectric system is stressed by transient voltages of wide varieties of waveshapes, caused by lightning as well as by switching. The rise (front) time

of a lightning-caused transient voltage varies from submicrosecond regime to about 10ms. The rise time of a switching surge is generally believed to be several hundred microseconds. However, certain types of circuit breakers (e.g., SF₆ and vacuum) can generate switching surges with rise times in the nanosecond regime. Considerable worldwide interest has focused on the breakdown characteristics of long air gaps under the slow-rising (several hundred microseconds) switching surges. This is understandable; the switching-surge breakdown voltage level of a long air gap under certain conditions can be dangerously close to the power-frequency operating voltage of an ultra-high-voltage power-transmission line. However, the outages of the bulk of the transmission and distribution systems

of lower voltage levels are caused by the lightning surges. Sphere-sphere, rod-rod, and rod-plane air gaps, each 5-cm (2-in.) long, were tested with lightning surges of eight voltage waveshapes of both polarities. The critical breakdown voltage of the tested air gaps showed a minima at a certain voltage wavefront. Long time delays of breakdown for the fast-front and short time delays for the slow-front waves

were observed. These phenomena would significantly affect the insulation coordination of the power apparatus and systems.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aInstitute of Electrical and Electronic Engineers.

^bTennessee Tech University.

[7.4.51] Potential Impact of Superconductivity on Power Quality Enhancement

B. W. McConnell

(Abstract of *Proceedings of the Sixth Annual Conference on Superconductivity and Applications*, American Institute of Physics, Buffalo, September 15–17, 1992)

In a perfect world, all electricity would be delivered at a defined frequency and precise voltage level without interruption or any distortion. For a variety of reasons, in the real world, this ideal is never reached and is not even required of the electricity supply. Until about 20 years ago, the only power disturbances of interest to utilities and most customers were complete outages lasting for longer than a few minutes. Customers were not particularly concerned by momentary outages, voltage variation, minor frequency variation, and harmonic content. During the last 15 years, the use of electronically controlled equipment, which is often sensitive to even slight voltage aberrations, has increased dramatically. This increased vulnerability of all segments of the economy to momentary voltage variation has

resulted in increased emphasis on power quality. In fact, electric power quality problems are estimated to cost U.S. industry \$26 billion dollars per year in lost production. This paper provides a summary of the magnitude of the problem and an overview of the underlying causes, discusses the methods used by industry to reduce the impact and the associated cost, and examines the potential for superconducting technology to effect alternative solutions. The paper also discusses the present market for uninterruptible power supplies and power conditioners and summarizes the benefits of applying high-temperature superconductors.

Research sponsored by the U.S. Department of Energy Office of Advanced Utility Concepts.

[7.4.52] Experimental Determination of the MHD-EMP Effects on Power Distribution Transformers

B. W. McConnell

P. R. Barnes

F. M. Tesche^a

(Abstract of *Proceedings of the 1992 HEART Conference*, Albuquerque, N.M., February 24–28, 1992)

The detonation of a high-altitude nuclear explosion is known to affect the magnetosphere, producing late-time variations of the earth's magnetic field for several hundreds of seconds. Known as the magnetohydrodynamic electromagnetic pulse (MHD-EMP), or E₃, this environ-

ment is of particular concern for electrical power systems in the event of a nuclear attack. Its effects are similar to those of geomagnetic storms. This paper documents an experimental program designed to better understand the behavior of distribution-class transformers sub-

jected to quasi-dc current excitation. Given the knowledge of the MHD-EMP-induced current flowing in a long power line, and the transformer response characteristics obtained in this program, researchers can make more accurate assessments of the behavior of the overall power system to EMP. The experimental program involved constructing a mock-up of a simple 3-phase 12.47-kV distribution system using two distribution-class transformers and a dummy 3-phase load bank. This system was fed by local commercial power. Measurements on this system were made with the following specific objectives in mind:

- to determine the effect of quasi-dc currents on the operation of three-phase transformer banks;

- to measure voltage and current harmonics within the system and at the loads;
- to assess the importance of the quasi-dc current duration;
- to determine the change in reactive power demand as a function of quasi-dc currents; and
- to determine if low-level quasi-dc currents and the distorted ac current can cause primary fuses to blow.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aElectromagnetics Consultant.

[7.4.53] Impact of Quasi-DC Currents on Three-Phase Distribution Transformer Installations

B. W. McConnell
P. R. Barnes

F. M. Tesche^a
D. A. Schafer^b

(Abstract of ORNL/Sub/89-SE912/1, Oak Ridge National Laboratory, June 1992)

This report summarizes a series of tests designed to determine the response of quasi-dc currents on three-phase power distribution transformers for electric power systems. In general, if the dc injection is limited to the primary side of a step-down transformer, significant harmonic distortion is noted, and an increase in the reactive power demand results. For dc injection on the secondary (load) side of the step-down transformer, the harmonic content at the secondary side is quite high, and saturation occurs with a relatively low level of dc injection. However, the reactive power demand is significantly lower. These tests produced no apparent damage to the transformers. Transformer damage is dependent on the duration of the dc excitation, the level of the excitation, and the thermal characteristics of the transformer.

Results show that the transformer response time is much shorter than seen in power transformer

tests at lower dc injection levels. This shorter response time suggests that the response time is strongly dependent on the injected current levels and that higher levels of dc injection for shorter durations could produce very high reactive power demands and harmonic distortion within a few tenths of a second. The added reactive power load could result in the blowing of fuses on the primary side of the transformer for even moderate dc injection levels, and neutral currents are quite large under even low-level dc injection. This "smoking neutral" results in possible equipment failure as well as in high-level harmonic injection into equipment via the neutral.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aConsultant.

^bMission Research Corporation.

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[7.4.54] Modeling Study Examining the Performance of Retrofitted Exterior Masonry Wall Insulation

H. A. McLain
K. E. Wilkes
M. P. Ternes

(Abstract of *Proceedings of the ASHRAE/DOE/BTECC Conference, Thermal Performance Of the Exterior Envelopes of Buildings V*, Clearwater Beach, Fla., December 7–10, 1992)

A field test was performed during the summer of 1991 in Scottsdale, Arizona, to evaluate the space-cooling electricity savings and potential for reducing electricity demand of retrofitted exterior masonry wall insulation for existing single-family houses. Eight houses (approximately 20 years old) were monitored in the field test. These were occupied, detached, single-family houses (no mobile homes) with uninsulated masonry walls, unfinished exteriors, and only central electric air-conditioning systems. At the midpoint of the summer monitoring period, insulation was installed on the exterior masonry wall surfaces. Total house and air-conditioning electricity consumptions were monitored during the entire test period. This paper focuses on the

results of a modeling study performed in conjunction with the field test. The air-conditioning electricity consumption in the houses before and after the addition of the exterior wall insulation was estimated using the DOE-2.1D simulation program, coupled with a detailed attic performance model, and using the measured weather data. The calculated levels of electricity consumption were compared to measured data to verify the accuracy of the simulations. These programs were then used to estimate the annual energy savings and electricity demand reductions for this conservation measure in different climates.

Research sponsored by the U.S. Department of Energy Office of Buildings Research.

[7.4.55] Study of Thermoelectric Technology for Automobile Air Conditioning

V. C. Mei
F. C. Chen

B. Mathiprakasam^a
P. Heenan^a

(Abstract of *Proceedings of the ASME 1991 Winter Annual Meeting*, Atlanta, December 1–6, 1991)

An analytical study was conducted to determine the feasibility of employing thermoelectric (TE) cooling technology in automobile air conditioners. The study addressed two key issues—power requirements and availability of TE materials. In this paper, a mathematical model was developed to predict the performance of TE air conditioners and to analyze power consumption. Results show that the power required to deliver a cooling capacity of 4 kW (13,80 Btu/h) in a 38°C (100°F) environment will be 9.5 kW electric.

Current TE modules suitable for air conditioning are made of bismuth telluride. The element tellurium is expected to be in short supply if TE cooling is widely implemented for auto air conditioning; some available options are studied and presented in this paper.

Research sponsored by the U.S. Department of Energy Office of Transportation Technologies.

^aMidwest Research Institute.

[7.4.56]

Analysis of Non-CFC Automotive Air Conditioning

V. C. Mei
F. C. Chen
R. Sullivan^a

(Abstract of *Proceedings of the International CFC & Halon Alternatives Conference*,
Baltimore, December 3-5, 1991)

Concern about the destruction of the global environment by chlorofluorocarbon (CFC) fluids has become an impetus to search for non-CFC refrigerants and cooling methods for mobile air conditioning (MAC). While MAC is still optional, its market share has reached 90% in passenger cars and 70% in light trucks in North America. MAC accounts for an estimated 33% of all R-12 consumption in the United States and for more than 30% of R-12 use in Japan. MAC also accounts for about 7% of total fuel consumption for a passenger car. Furthermore, a significant potential for growth exists in the MAC field as the use of private cars and trucks becomes more

common in other parts of the world. While some alternative refrigerants have been identified, they are not considered a lasting solution because of their high global-warming potential, which could result in their eventual phase-out. In view of this dilemma, environmentally acceptable alternative cooling methods have become important. This study discusses the advantages and the limits of some of the alternative automotive cooling methodologies.

Research sponsored by the U.S. Department of Energy.

^aU.S. Department of Energy.

[7.4.57] An Assessment of Desiccant Cooling and Dehumidification Technology

V. C. Mei
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Z. Lavan^a
R. K. Collier^b

(Abstract of ORNL/CON-309, Oak Ridge National Laboratory, July 1992)

Desiccant systems are heat-actuated cooling and dehumidification technology. With the recent advances in this technology, desiccant systems can now achieve a primary energy coefficient of performance between 1.3 and 1.5, with potential to reach 1.7 and higher. Two important and well-known advantages of desiccant cooling systems are that they are chlorofluorocarbon-free and can reduce electricity peak load. Another important but lesser-known advantage of desiccant technology is its potential for energy conservation. The energy impact study in this report indicates that a 13% energy savings in residential cooling and 8% savings in commercial cooling are possible. Great energy-saving potential also exists in the industrial sector if industrial waste heat can be used of desiccant regeneration. The latest study on desiccant-integrated building heating, ventilating, and air-conditioning sys-

tems indicated that the initial cost for the conventional cooling equipment was greatly reduced by using desiccant technology because of downsized compressors, fans, and ductwork. This cost reduction was more than enough to offset the cost of desiccant equipment. System operation cost was also reduced. These data indicate that desiccant systems are cost-effective. This study provides a state-of-the-art assessment for desiccant technology in the field of desiccant materials, systems, computer models, and theoretical analyses. From this information, technology options were derived, and future research and development needs were identified. A historic overview lists what has already been done and who is doing what. This information will help project the future of this technology. Because desiccant technology has already been applied in the commercial building sector with

encouraging results, future market breakthroughs will probably start in this sector. Therefore, the report includes a market analysis for commercial building applications.

Research sponsored by the U.S. Department of Energy.

^aIllinois Institute of Technology.

^bCollier Engineering Services.

^cGershon Meckler Associates P.C.

[7.4.58]

Alternative Non-CFC Mobile Air Conditioning

V. C. Mei
F. C. Chen
D. M. Kyle

(Abstract of ORNL/CON-335, Oak Ridge National Laboratory, September 1992)

Concern about the environmental impact of chlorofluorocarbon (CFC) fluids has spurred the search for alternative, non-CFC refrigerants and cooling methods for mobile air conditioning (MAC). Some alternative refrigerants have been identified, but they are not considered a lasting solution because their high global-warming potential could result in eventual phaseout. This report is aimed mainly at the study of alternative automotive cooling methodologies, although it briefly discusses the current status of alternative refrigerants. Alternative MACs can be divided into work-actuated and heat-actuated systems.

Work-actuated systems include conventional MAC, reversed Brayton air cycle, rotary vane compressor air cycle, Stirling cycle, and thermoelectric cooling. Heat-actuated MACs include metal hydride cooling, absorption cooling, ejector cooling, and absorption cycle. While researchers are more experienced with some work-actuated cycle systems, heat-actuated cycle systems have a high potential for energy savings with possible waste-heat applications. This study discusses the advantages and limitations of each alternative cooling method.

Research sponsored by the U.S. Department of Energy.

[7.4.59] Development and Proof-Testing of Advanced Absorption Refrigeration Cycle Concepts (Report on Phases I and 1A)

R. J. Modahl
F. C. Hayes^a

(Abstract of ORNL/Sub/86-17498/1, Oak Ridge National Laboratory, March 1992)

The overall objectives of this project are to evaluate, develop, and proof-test advanced absorption refrigeration cycles that apply to residential and commercial heat pumps for space conditioning. The heat-pump system is to be direct-fired with natural gas and will use absorption working fluids with known properties. The project is divided into three phases. Phase I entails the analytical evaluation of advanced cycles and included the selection of preferred concepts for further development. Phase II involves the development and testing of critical

components and a complete laboratory breadboard version of the selected system. Phase III, the development of a prototype unit, is contingent on successful completion of phase II. This report covers phase I work, which included evaluating 24 advanced absorption cycle/fluid combinations and developing computer models to predict system performance. Coefficient of performance, theoretical pump power, and internal heat exchange were calculated for each system, and these calculations were used to indicate operating and installed costs to rank the

relative promise of each system. The highest ranking systems involve the cycle concepts of absorber/generator heat exchange, generator heat exchange/absorber heat exchange, regeneration, and resorption/desorption, in combination with the $\text{NH}_3/\text{H}_2\text{O}/\text{LiBr}$ ternary absorption fluid mixture or with the $\text{NH}_3/\text{H}_2\text{O}$ binary solution. The user economic analysis concludes that the gas-fired absorption heat pump can be an attractive alternative in the commercial market, especially in areas with high heating loads. The economic analysis shows simple payback and internal rate of return to be about the same for a highly complicated advanced cycle using the ternary solution and for a relatively simple advanced cycle using the binary solution when compared to a conventional gas boiler and air-cooled reciprocating compressor chiller.

Therefore, the simpler cycle, which involves absorber heat exchange, absorber/generator heat exchange, and generator heat exchange using $\text{NH}_3/\text{H}_2\text{O}$, was chosen for initial breadboard testing in phase II. Compared to the conventional, electric air-conditioner/gas boiler system used as the reference system in this study, the gas-fired advanced absorption cycle heat pump accomplishes the U.S. Department of Energy's goal of conserving and provides much more balanced loads for both electric and gas utilities. Based upon these conclusions, the recommendation was made to proceed to phase II, the laboratory breadboard proof-of-concept.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aThe Trane Company.

[7.4.60] Magnetic Refrigeration Cycle Analysis Using Selected Thermodynamic Property Characterizations for Gadolinium Gallium Garnet

R. W. Murphy

(Abstract of *Proceedings of the Sixth Annual Conference on Super-Conductivity and Applications*, Buffalo, September 15-17, 1992)

Magnetothermodynamic property characterizations were selected, adapted, and compared to material property data for gadolinium gallium garnet in the temperature range 4-40 K and magnetic field range 0-6 T. The most appropriate formulations were incorporated into a model in which methods similar to those previously developed for other materials and temperature ranges were used to assess limitations and relative performance of Carnot, ideal regen-

erative, and pseudo-constant field regenerative cycles. Analysis showed that, although Carnot cycle limitations on available temperature lift for gadolinium gallium garnet are not as severe as those for materials previously examined, substantial improvements in cooling capacity/temperature lift combinations can be achieved using regenerative cycles within specified field limits if significant loss mechanisms are mitigated.

Research sponsored by the U.S. Department of Energy.

[7.4.61] Evaluation of the Computerized Utilities Energy Monitoring and Control System Installed at the U.S. Military Community at Goeppingen, Germany

S. L. Purucker
M. B. Gettings

(Abstract of ORNL/CON-342, Oak Ridge National Laboratory, November 1991)

Under the provisions of an interagency agreement between the U.S. Army and the Depart-

ment of Energy, the Oak Ridge National Laboratory is evaluating the Utilities and Energy Moni-

toring and Control System (UEMCS) installed at the U.S. Military Community Activity at Goeppingen, Germany. This evaluation relies on examination of existing data and information to determine the effectiveness of UEMCS. UEMCS is a supervisory control system with distributed intelligence in local process controllers. The local controllers perform the following basic functions: (1) adjusting building district-heat temperature based on outside air temperature, (2) maintain domestic hot water at a constant temperature, (3) adjusting district-heat water-pump speeds to maintain a constant flow of warm water through each register, and (4) maintaining desired room temperatures in buildings

that require ventilation. Though the conversion to district heat has produced the most energy savings, the UEMCS day/night setback program also contributes substantially, with additional savings from start/stop programs (such as seasonal switchover) and various temperature-control programs. Further opportunities for savings exist in increasing monitoring and control of water usage and connecting the community's electrical network to UEMCS, permitting demand-limiting and increased power-factor control.

Research sponsored by the U.S. Department of Energy and the U.S. Army Europe.

[7.4.62] Corrosion Screening of Potential Fluids for Ammonia/Water Absorption Cycles

R. H. Reiner
A. Zaltash

(Abstract of ORNL/CF-92/41, Oak Ridge National Laboratory, February 1992)

Corrosion rates of several steel alloys in absorption fluid mixtures containing ammonia (NH_3), water (H_2O), and various inorganic salts have been measured at temperatures between 60°C and 100°C. The inorganic salts were used as ternary and quaternary fluid additives in these mixtures to reduce the H_2O vapor pressure and to expand the fluid operating temperature range. Electrochemical measurements indicate that most of the ternary and quaternary fluids were much more corrosive than $\text{NH}_3/\text{H}_2\text{O}$. Two ab-

sorption fluids that show promise are quaternary mixtures of LiBr , LiNO_3 , H_2O , and NH_3 . These quaternary fluids provide good H_2O vapor pressure depression and are only moderately corrosive to common steel alloys. Either quaternary fluid might be a potential "drop-in" replacement fluid to reduce rectification heat losses in the generator-absorber heat exchange cycle.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.63] Densities and Viscosities of Ternary and Quaternary Ammonia/Water Fluids

R. H. Reiner
A. Zaltash

(Abstract of ORNL/CF-92/42, Oak Ridge National Laboratory, March 1992)

This report discusses the measured densities, viscosities, and boiling points (at barometric pressure) of solutions formed by inorganic salts dissolved in an ammonia/water solvent. These ternary or quaternary solutions of ammonia/water/dissolved salts are being investigated

to reduce rectification requirements and to expand the temperature range of ammonia/water in advanced absorption cycles. Densities and viscosities of these fluids were measured over the temperature range of 283.15 to 343.15 K (10.0 to 70.0°C). Observed densities and viscosities

were expressed as empirical functions of temperature by means of the least-squares method.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.64] Benchmark Performance Analysis of an ECM-Modulated Air-To-Air Heat Pump with Reciprocating Compressor

C. K. Rice

(Abstract of *Proceedings of the 1992 ASHRAE Semi-Annual Meeting*, Anaheim, Calif., January 26–29, 1992)

A benchmark analysis was conducted to predict the maximum steady-state performance potential of a near-term modulating residential-size heat pump. Continuously variable-speed, permanent-magnet electronically commutated motors (ECMs) were assumed to modulate the compressor and the indoor and outdoor fans in conjunction with existing modulating reciprocating compressor technology. A modulating heat pump design tool was used to optimize this ECM benchmark heat pump, using speed ranges and total heat-exchanger sizes per-unit-capacity equivalent to those used by the highest seasonal energy-efficiency ratio (SEER)-rated variable-speed unit currently on the market (SEER = 16.4). Parametric steady-state performance optimization was conducted at a nominal design cooling ambient of 95°F (35°C) and at three off-design ambients of 82°F (27.8°C) cooling and 47°F and

17°F (8.3°C and -8.3°C) heating. An optimal control strategy was defined as a function of compressor speed to generate performance maps vs speed and ambient temperature for the heating and cooling modes. These maps were used to predict the seasonal and annual performance factors of the ECM benchmark case for an 1800 ft² (167.2 m²) house in a U.S. Department of Energy Region IV city, and the results were compared to those from a similar seasonal analysis for three commercially produced variable-speed heat pumps (based on available manufacturers' data). Conventionally sized and 50%-oversized units were considered. An SEER of 20 appears to be the limit of present modulated reciprocating technology with conventional sizing and default cycling loss factors.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.65] Proceedings: Workshop on Real-Time Control and Operation of Electric Power Systems, Denver, November 19–21, 1991

D. T. Rizy
W. E. Myers^a

L. E. Eilts^b
C. L. Clemans^b

(Abstract of CONF-9111173, Oak Ridge National Laboratory, July 1992)

A workshop was sponsored by the U.S. Department of Energy (DOE) Office of Energy Management to define the research and development (R&D) needs and their priority and timing for real-time control and operation of electric power systems. The workshop consisted of an opening plenary session with several speakers; four technical sessions, during which 13 topical papers were presented; a workshop session; and a final session during which working group results

were presented and discussed. The four technical areas that served as the topics for the working groups during the technical sessions included advanced power system technologies; advanced measurement, communication, and information systems; new modeling, analysis, and computation techniques; and intelligent and adaptive power system control and operations. The four working groups that met after the technical sessions identified 39 R&D needs for real-time

control and operations in a follow-up meeting. Oak Ridge National Laboratory (ORNL), representatives of DOE, the DOE power-marketing administrations (BPA and Western Area Power Administration), the Electric Power Research Institute, and the working group chairpersons and secretaries consolidated and organized those 39 areas into six major areas: (1) optimal transmission system operation; (2) optimal distribution system operation; (3) advanced power system

technologies; (4) on-line sensing systems; (5) local control; and (6) power system engineering research needs. All of these papers and meetings provide input to a multi-year program plan to be prepared by ORNL and DOE.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aBonneville Power Administration.

^bWestern Area Power Administration.

[7.4.66] Modeled Performance of Non-Chlorinated Substitutes for CFC-11 and CFC-12 in Centrifugal Chillers

J. R. Sand
S. K. Fischer
P. A. Joyner^a

(Abstract of *Proceedings of the International CFC and Halon Alternatives Conference*, Baltimore, December 3-5, 1991)

Current scientific evidence indicates that stratospheric chlorine concentrations below two parts-per-billion will be necessary to reverse and prevent "ozone hole" formations over Earth's polar regions each spring. This makes it unlikely that hydrochlorofluorocarbon (HCFC) alternatives with non-zero ozone depletion potentials will be accepted as refrigerants or blowing agents for foamed insulations for the long term. Pressure to eventually eliminate all high-volume uses of chlorine-containing refrigerants provides a strong incentive to find HFC or alternative, chlorine-free compounds with pressure-volume-temperature characteristics similar to R-11 and R-123 for new and existing large centrifugal chiller applications. Stable chlorine-free compounds with normal boiling points near CFC-11 and HCFC-123 are found in fluorinated propane or butane and fluorinated ether families. These larger molecules have larger vapor phase heat capacities and molecular weights, and lower critical temperatures, that thermodynamically decrease their volumetric capacity and coefficient of performance in simple cycle applications. However, larger molar latent heats of vaporization caused by hydrogen bonding in the ethers may improve their net refrigerating effect (volumetric capacity) over CFC-11 and HCFC-

123. A number of fluorinated alkanes and fluorinated ethers identified in earlier technical publications or in joint Electric Power Research Institute/U.S. Environmental Protection Agency projects aimed at synthesizing and partially characterizing a third generation of CFC alternatives were fitted to the Lee-Kessler-Plocker and Carnahan-Starling-DeSantis equations of state. Refrigerant property routines based on these equations were used to simulate the performance of a centrifugal chiller with pure refrigerants and nearly azeotropic refrigerant mixtures of these alternatives. Several chlorine-free compounds give modeled chiller performance comparable to CFC-11 and HCF-123 and better than CFC-12 and HFC-134a. Blends of these refrigerants may be required to decrease the flammability of some of the alternatives that show the best performance, and modifications to the current chiller cycle (such as liquid subcooling and suction gas superheat) may offer unique advantages for more complicated, larger refrigerant molecules.

Research sponsored by the U.S. Department of Energy Office of Building Technologies, and the Electric Power Research Institute.

^aElectric Power Research Institute.

**[7.4.67] Public Involvement In Integrated Resource Planning:
A Study of Demand-Side Management Collaboratives**

M. Schweitzer

J. Raab^a

(Abstract of ORNL/CON-2, Oak Ridge National Laboratory, February 1992)

In recent years, many utilities and nonutility parties (NUPs) across the country have tried a new approach to reaching agreement on demand-side management (DSM) program design and policy issues. Through this new approach, called the DSM collaborative process, parties who have often been adversaries in the past attempt to reach consensus rather than using traditional litigation to resolve differences. This report, the first comprehensive, in-depth review and assessment of collaboratives, examines nine cases of DSM collaboration involving 24 utilities and approximately 50 NUPs in 10 states. Collaboratives are described in terms of four major contextual and organizational characteristics: regulatory and legal history, parties involved and parties excluded, collaborative scope, and the collaborative process itself. Collaborative success is evaluated in terms of eight measures of performance:

- achievement of consensus by participants,
- approval of the resulting DSM plan by state regulators and courts (if appealed),

- satisfaction of participants' objectives,
- savings of time and money compared to the likely results of traditional litigation strategies,
- comparison of the outputs of the collaborative with those likely to result from the traditional adversarial process,
- changes in historic relations among the parties,
- plan implementation, and
- collaborative longevity.

Overall, the study indicates that DSM collaboratives have been successful according to a broad array of criteria. This report identifies a number of relationships between successful outcomes and various contextual and organizational characteristics of collaboratives.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aConsultant, Boston.

**[7.4.68] Proof of Concept of A Magnetically Coupled
Stirling Engine-Driven Heat Pump**

J. A. Shonder

G. Chen^a

J. McEntee^a

(Abstract of *Proceedings of the 27th Intersociety Energy Engineering Conference*, San Diego, August 3-7, 1992)

A prototype magnetically coupled Stirling engine-driven heat pump module has been designed and fabricated by Sunpower, Inc., under sponsorship of the U.S. Department of Energy and the Oak Ridge National Laboratory. Preliminary testing indicates that the magnetic coupling

is an effective means for transmitting power from a free-piston Stirling engine to a refrigerant compressor. Compared with other power-transmission concepts, the magnetic coupling has relatively low cost and will help make commer-

cial development of Stirling-driven heat pumps more likely in the future.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aSunpower, Inc.

[7.4.69] Report Style Guide for Subcontractors of the Efficiency and Renewables Research Section, Energy Division, Oak Ridge National Laboratory

T. A. Stone^a
M. N. Bennett^b

(Abstract of ORNL/TM-12082, Oak Ridge National Laboratory, September 1992)

This document has been paraphrased from the Oak Ridge National Laboratory (ORNL) *Document Preparation Guide*. It is intended for use by Efficiency and Renewables Research Section, Energy Division, ORNL subcontractors in preparing subcontractor reports so that review and editing effort can be minimized. Topics covered are typing instructions, document format, usage,

abbreviations and acronyms, and standard editing marks.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aMidwest Technical Inc.

^bIntern, Energy Division Publications Office.

[7.4.70] An Approach to Metering and Network Modeling

J. P. Stovall
M. M. Adibi^a

K. A. Clements^b
R. J. Kafka^c

(Abstract of *Proceedings of the American Power Conference*, Chicago, April 13–15, 1992)

Estimation of the static state of an electric power network has become a standard function in real-time monitoring and control. Its purpose is to use the network model and process the metering data to determine an accurate and reliable estimate of the system state in the real-time environment. The commonly used models assume that the network parameters and topology are free of errors and that the measurement system provides unbiased data having a known distribution. However, the network and metering models contain errors that frequently result in either non-convergent behavior of the state estimator or exceedingly large residuals, reduc-

ing the level of confidence in the results. This paper describes an approach to minimize the above uncertainties by analyzing the data routinely collected at the power system control center. The approach will improve the reliability of the real-time data base while reducing the state estimator installation and maintenance effort.

Research sponsored by the U.S. Department of Energy.

^aIRD Corporation.

^bWorcester Polytechnic Institute.

^cPotomac Electric Power Company.

[7.4.71] Energy Efficiency Evaluation of the Housing Community Plan Developed for Shaw Air Force Base

M. P. Ternes
S. Scully^a

(Abstract of ORNL/TM-12033, Oak Ridge National Laboratory, May 1992)

The purpose of this project was to determine if energy efficiency is adequately addressed in housing community plans being developed for Air Force Tactical Air Command bases. Although renovation work specified in the plans generally complies with current Air Force regulations and is generally consistent with public energy standards, the level of energy efficiency that should be readily attained after renovation will not necessarily be achieved. Design and construction flaws can exist in the housing that adversely affect energy consumption. These housing deficiencies are not completely addressed in the

current Air Force regulations or guidelines and thus are not addressed in the housing community plans. A four-fold plan is recommended to ensure that future plans address improvements in energy efficiency to the fullest extent possible. The recommendations include revising guidance documents, improving field inspections, and implementing monitoring programs.

Research sponsored by Civil Engineering Squadron, Shaw Air Force Base.

^aNational Association of Home Builders Research Center.

[7.4.72] Installation Consideration for Retrofitted Exterior Masonry Wall Insulation

M. P. Ternes
K. E. Wilkes
K. Rossi^a

(Abstract of *Proceedings of the International Symposium on Exterior Insulation and Finish Systems (EIFS): Performance of EIFS Worldwide*, Washington, D.C., September 21–24, 1992)

Masonry construction for single-family houses is a common construction technique that has been practiced predominately in southern climates. Techniques for insulating the exterior walls of masonry houses and the energy performance of exterior insulation applied to masonry homes have not been extensively documented. A field test was performed during the summer of 1991 in Scottsdale, Arizona, to evaluate the space-cooling electricity savings and potential for reducing electricity demand of retrofitted exterior masonry wall insulation for existing single-family houses. Eight houses (approximately 20 years old) were monitored. These were occupied, detached, single-family houses (no mobile homes) with uninsulated masonry walls, unfinished exteriors, and only central electric air-conditioning systems. At the midpoint of the

summer monitoring period, insulation was installed on the exterior masonry wall surfaces. This paper presents, in detail, the techniques and specifications used to install the insulation on the field-test houses. Installation specifications were developed for the field test following extensive discussions with Western Stucco Systems, DOW Chemical, and local contractors. This report presents results of this experience, documents problems encountered in performing the field-test installations, and discusses solutions to these problems. Other feedback on the installations obtained from the homeowners and contractors is also discussed.

Research sponsored by the U.S. Department of Energy Office of Buildings Research.

^aArizona Energy Office.

[7.4.73]**Experimental Plan for the Fuel-Oil Study**

M. P. Ternes

W. P. Levins

M. A. Brown

(Abstract of ORNL/TM-11668/V2, Oak Ridge National Laboratory, January 1992)

An up-to-date assessment of the Weatherization Assistance Program (WAP) is being performed by the U.S. Department of Energy WAP Division and the Oak Ridge National Laboratory. Five studies form the evaluation. Major goals of the Fuel-Oil Study are to estimate the fuel oil saved by the WAP in the Northeast during the program years (PYs) 1990 and 1991, identify and quantify non-energy impacts of the WAP, assess the cost-effectiveness of the WAP within this sub-market, and assess factors that may cause savings and cost-effectiveness to vary. The study will analyze only single-family houses in the nine states in the Northeast census region and will be carried out over two heating seasons (PYs 1990 and 1991). The study will use split-winter, pre- and post-weatherization experimental design with a control group. Houses will be monitored over one winter. Energy conservation measures will be installed in the weatherized houses in January of each winter by the local WAP subgrantee. One-hundred twenty five weatherized houses and 75 control houses will be monitored over the 1990–1991 winter; a different set of 200 houses will be monitored over the 1991–1992 winter. The houses will be evenly distributed among 25 subgrantees. Space-heating fuel-oil consumption, indoor temperature, and outdoor temperature data will be collected for all houses. Fuel-oil delivery data will be collected for each house monitored over the 1990–1991 winter for at least a year before weatherization. The delivery data will be analyzed to determine if the accuracy of the study can be improved by collecting fuel-oil delivery

data on a larger sample of houses over the 1991–1992 winter. Detailed survey information will be obtained on all the houses, including descriptive details of the house and its mechanical systems, details on household size and other demographics, and occupant answers to questions regarding comfort, safety, and operation of their space-heating system and house. Information will be collected from the subgrantees on the measures installed in each weatherized house and their costs, the administrative and program support costs for the subgrantee, and details on the overall program approach of the subgrantee. Information on state costs and program approaches will be collected from the grantees. In addition to this survey information, air leakage and space-heating system steady-state efficiency will be measured before and after weatherization in all houses. A safety inspection of the space- and water-heating systems will also be performed in all houses following weatherization. Normal annual space-heating fuel-oil consumption levels needed to calculate savings will be estimated from the pre- and post-weatherization submetered data using a house energy consumption model. Program-induced improvements in the affordability of housing and space-heating, together with improvements in safety and comfort, will be assessed. The cost-effectiveness of weatherization measures alone will be examined using appropriate economic indicators. Factors affecting fuel-oil savings and cost-effectiveness will be assessed.

Research sponsored by the U.S. Department of Energy Office of Technical and Financial Assistance.

[7.4.74] Cost Effectiveness of Retrofitted Exterior Masonry Wall Insulation

M. P. Ternes
K. E. Wilkes
K. Rossi^a

(Abstract of *Proceedings of the 1992 ACEEE Summer Study on Energy Efficiency in Buildings*,
American Council for an Energy-Efficient Economy, Pacific Grove, Calif.,
August 30–September 5, 1992)

Masonry construction for single-family houses is a common construction technique predominately practiced in southern climates. Techniques for insulating the exterior walls of masonry houses have not been extensively developed, and the energy performance of exterior insulation applied to masonry homes has not been extensively documented. A field test involving eight similar houses (approximately 20 years old) was performed in Scottsdale, Arizona, to evaluate the space-cooling electricity savings and potential for reducing electricity demand of exterior wall insulation applied to uninsulated masonry walls of existing single-family residential buildings. This paper summarizes the space-cooling electricity savings and electricity

demand reductions measured in the eight field-test houses that can be attributed to installation of the exterior wall insulation. This paper also presents the cost-effectiveness of the achieved savings and reductions. A separate modeling study was performed to estimate savings and demand reductions of similar houses located in different climatic regions; these results and their cost-effectiveness are also presented. The paper also examines appropriate rebate levels comparable to those given by utilities, for example, for high-efficiency air conditioners.

Research sponsored by the U.S. Department of Energy Office of Buildings Research.

^aArizona Department of Commerce.

[7.4.75] Overview of CFC Replacement Issues for Household Refrigeration

E. A. Vineyard
L. Roke^a
F. Hallett^b

(Abstract of *Proceedings of the International CFC and Halon Alternatives Conference*,
Baltimore, December 3–5, 1991)

In accordance with Article 6 of the *Montreal Protocol*, the countries that signed the agreement to phase out production and use of chlorofluorocarbons (CFCs) shall periodically assess the control measures provided for in the *Protocol*. As part of that assessment process, household refrigeration was investigated to determine the status of CFC-12 replacements. Domestic refrigeration, with a worldwide market of approximately 56 million annual sales, is an important end-user of CFCs. The vapor-compression cycle used in the majority of units uses CFC-12 as its

working fluid. The assessment concluded that much progress has been made toward finding a suitable replacement. Compressors designed for HFC-134a have efficiencies comparable to those for CFC-12, and acceptable reliability tests have been obtained with ester lubricants. In addition, other replacements such as R-152a and refrigerant mixtures exist, but they will require more study. Cycle options, such as the Stirling cycle, may be viable at some point in the future. The impact of new refrigerants is expected to result in elimination of CFC-12 consumption in devel-

oped countries by 1997 and in developing countries by 2005.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aFisher and Paykel, Greemount, Auckland, New Zealand.

^bPrigidaire.

[7.4.76] Evaporation Characteristics of R-22 Flowing Inside a Corrugated Tube

E. A. Vineyard
J. C. Conklin
D. L. Hinton^a

(Abstract of *Proceedings of the 1992 ASME National Heat Transfer Conference*, San Diego, August 9–12, 1992)

Replacements for the chlorofluorocarbon (CFC) refrigerants currently used in air conditioners and heat pumps are being investigated as part of the Building Equipment Research program at the Oak Ridge National Laboratory. Other investigators have measured heat transfer coefficients that were less than expected for some alternative refrigerants undergoing evaporation in smooth tubes. These alternative refrigerants would thus require additional heat transfer area. Because heat exchanger thermal performance has a direct influence on the overall cycle performance of vapor-compression refrigeration machinery, enhanced heat transfer surfaces are of interest to improve the efficiency of heat pumps and air conditioners. As part of a larger effort investigating nonazeotropic refrigerant mixtures for replacement of CFC compounds, this report investigates the performance of R-22 (chlorodifluoromethane) in conventional smooth tubes and enhanced heat transfer tube geometries as a base case. This paper presents the results of this initial investigation for a smooth tube and a tube with a commonly available enhanced heat

transfer surface, called corrugated or spirally indented. Researchers investigated the evaporating heat transfer and pressure drop characteristics in an experimental apparatus consisting of a variable-speed compressor and two sets of counterflow concentric-tube heat exchangers having both smooth and corrugated enhanced tube side surfaces. The refrigerant circulates inside the central tube, and water circulates in the annulus. The measured pressure drop and the heat transfer coefficient for the evaporation of the R-22 are presented as a function of heat flux, quality, and mass flux for both heat transfer surfaces. Both the heat transfer coefficient and the pressure drop of the corrugated surface are higher than those of the smooth surface at any given refrigerant condition. The heat transfer enhancement is most notable at low mass qualities.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

^aTennessee State University.

[7.4.77] Flow-Bolling Enhancement of R-22 and a Nonazeotropic Mixture of R-143a and R-124 Using Perforated Folds

E. A. Vineyard
J. C. Conklin

(Abstract of *Proceedings of the 1992 ASHRAE Annual Meeting*, Baltimore, June 27–July 1, 1992)

This paper investigates the flow-boiling heat transfer from the inside of a smooth tube and a

novel surface designed to improve nucleate boiling heat transfer. This surface consists of a

perforated brass foil inserted into the smooth tube. Two fluids were investigated: pure R-22, and a nonazeotropic refrigerant mixture (NARM) of 75% R-143a and 25% R-124 (by mass). The experiment was conducted in an apparatus consisting of a variable speed compressor with a range of 500 to 3000 rpm and a counterflow concentric-tube heat exchanger. The refrigerant circulates inside the central tube, and water circulates in the annulus. For R-22 the perforated

foil insert increased the heat-transfer coefficient of the smooth tube, particularly at lower qualities and heat fluxes, indicating augmentation of nucleate boiling. For this particular NARM, however, the perforated foil insert did not increase the heat transfer coefficient, which is most likely due to nucleate boiling suppression in NARMs at the qualities observed in the test.

Research sponsored by the U.S. Department of Energy Office of Building Technologies.

[7.4.78]

Domestic Refrigeration

E. A. Vineyard
L. Roke
F. H. Hallett

(Abstract of pp. 78-88 in *Montreal Protocol Assessment-Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Committee*, December 1991)

As part of the Montreal Protocol assessment process, household refrigeration was investigated to determine the status of chlorofluorocarbon (CFC)-12 replacements. The impact of new refrigerants is expected to result in elimination

of CFC-12 consumption in developed countries by 1997 and in developing countries by 2005.

Research sponsored by the U.S. Department of Energy Office of Building Technologies, Building Equipment Division.

[7.4.79] Persistence of the Impact of the Hood River Conservation Project on Typical and Peak Loads Three Years after Weatherization

D. L. White
T. K. Stovall^a
B. E. Tonn

(Abstract of ORNL/CON-321, Oak Ridge National Laboratory, February 1992)

The Hood River Conservation Project (HRCP) was a major residential retrofit demonstration project, operated by Pacific Power & Light Company (Pacific Power) between 1984 and 1988 and funded by the Bonneville Power Administration. The project was designed to install as many cost-effective retrofit measures in as many electrically heated homes as possible in the community of Hood River, Oregon. The Pacific Power HRCP planners statistically selected a special group of 320 Hood River homes that represented a cross-section of the community. The end-use

loads (electric space heating, electric water heating, and woodfuel space heating) and the interior temperatures of these homes were monitored for one year before weatherization and three years after weatherization. After more than four years of submetered data collection, 220 single-family, detached homes were available for analysis in this second load study. Three years after weatherization, these data show that load savings were persistent across the sample. Other analysis results show (1) significant differences in electricity use between homes heated

by wood and by electricity; (2) significant fuel-switching patterns; (3) negligible baseload electricity savings, and (4) erratic water-heating energy use.

Research sponsored by the Bonneville Power Administration Office of Energy Resources.

^aEngineering Technology Division.

[7.4.80] The Reliability of Residential Energy Conservation Resources

D. L. White
M. A. Brown

(Abstract of *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Berkeley, Calif., August 30–September 5, 1992)

In many regions of the United States, energy conservation is becoming a resource that can be bought and sold like output from power plants. However, the market value of conservation is distorted by uncertainty concerning its persistence and, hence, its reliability. This paper focuses on the reliability of residential energy conservation in the Bonneville Power Administration's (BPA's) Residential Weatherization Program (RWP). Three reliability issues are addressed: the persistence of energy savings over time for each cohort of RWP participants; the decline in conservation resources from one RWP cohort to the next; and patterns in energy savings compared with changes in the nature of the RWP, the participants, and electricity prices. BPA has operated RWPs for the last ten years and has evaluated seven of those program years. To

increase its understanding of the persistence of energy savings over time, BPA revisited the 1983 program to evaluate energy use patterns for six years after weatherization. Generally, once achieved, savings from residential energy conservation programs tend to persist. Four of the participant cohorts that were followed for three or more postretrofit years demonstrate that net savings in the second year after weatherization are always lower than first-year net savings. However, third-year savings do not always continue to decline. Moreover, six-year savings are only 27% below those achieved in the first year after weatherization. Patterns in energy savings over time are correlated with pretetrofit electricity consumption, program expenditures, and levels of consumer cost-sharing.

Research sponsored by the U.S. Department of Energy.

[7.4.81] HEMP-Induced Transients in Electric Power Substations

C. M. Wiggins^a
D. E. Thomas^a
T. M. Salas^a

(Abstract of ORNL/Sub/88-SC863, Oak Ridge National Laboratory, October 1991)

A nuclear detonation in or above the earth's atmosphere produces an intense electromagnetic pulse (EMP). A large portion of the EMP electromagnetic energy is within the radio-frequency spectrum. The electromagnetic fields radiated by the blast vary greatly with weapon characteristics, yield, and detonation height. A detonation at altitudes above 40 km (25 miles) produces an EMP called high-altitude EMP

(HEMP), a steep-front short-duration transient with a rise time of a few nanoseconds that decays to near zero in less than a microsecond. A single high-altitude burst can subject much of the continental United States to intense HEMP electric fields of tens of kilovolts per meter. This intense transient HEMP will induce fast transients in high-voltage transmission lines and bus structures, instrumentation cables, and control

wires in power transmission and distribution substations. A system of traveling wave coupling models for a 500-kV substation, including models for the high-voltage primary bus, components (circuit breakers, disconnect switches, power transformers, and current and voltage instrument transformers), low-voltage control wiring circuits, and a number of conducted and radiated interference coupling modes, had been developed earlier by the Electric Power Research Institute (EPRI) under project RP2674-1 to study substation interference effects caused by switching transients, faults, and lightning. These EPRI models served as the base line for the present HEMP coupling investigations. The HEMP ef-

fects on protective relays were assessed for a nominal HEMP environment using several new field coupling models merged with the switching transient data. A representative solid-state relay is unlikely to be damaged or to misoperate by the nominal HEMP threat with a peak field strength of 50 kV/m. However, it is possible for both dc control wires to flash over to ground simultaneously, causing fuses to blow and placing the relay in an inoperative state.

Research sponsored by the U.S. Department of Energy Office of Energy Management.

^aBDM International Inc., Albuquerque, N.M.

[7.4.82] The Demand-Side Management Program Development Process— A Utility Perspective

A. K. Wolfe
N. E. Yourstone^a

(Abstract of ORNL/CON-345, Oak Ridge National Laboratory, March 1992)

This report describes the findings from an Oak Ridge National Laboratory study of the demand-side management (DSM) program development processes of 13 electric utilities. The study is based on lengthy telephone interviews with utility personnel, interviews made during site visits to three utilities, documents sent by utilities on their process, and published literature. The telephone interviews followed a protocol that focused primarily on obtaining an overview of the DSM program development process and, secondarily, on uncovering the bases for making decisions. Because the study is exploratory, it does not draw conclusions about an optimal planning process. Rather, this study allows outsiders to peer inside the DSM planning "black box" and gain insight into the factors that motivate and affect DSM programs from the utility's perspective. The study also provides utility planners information against which to compare their own beliefs, perceptions, and motivations about DSM planning. Two types of DSM program development were discerned: technology oriented and customer oriented. Utilities characterized as technology-oriented generally approach DSM from an engineering perspective,

emphasizing the technical feasibility and the energy impacts of various technologies. Utilities characterized as customer-oriented emphasize the importance of customer needs and attempt to offer DSM programs that satisfy those needs. These two orientations most noticeably affect the stage in the program development process in which customer needs and technologies are considered. The study also explores the impacts of organizational factors, external influences, market segmentation, estimates of program participation, incentives, and program evaluations upon program development. Finally, the study identifies key decisions about the planning process that utilities new to DSM must make. The primary recommendation regarding DSM program development is for utilities to document that process in greater detail than is currently done. In particular, utilities evaluating their current process or beginning DSM programs would benefit from documentation and standardization.

Research sponsored by the U.S. Department of Energy Office of Conservation and Renewable Energy.

^aConsultant, Albuquerque, N.M.

[7.4.83]

**Thermal Performance of HCFC-22 Blown Extruded
Polystyrene Insulation**

D. W. Yarbrough

R. S. Graves

J. E. Christian

(Abstract of *Proceedings of the American Society for Testing and Materials*,
Gatlinburg, Tenn., October 1991)

A closed-cell foamboard insulation containing chlorodifluoromethane (HCFC-22) has been monitored in the laboratory and in the field for about 3 years. Experimental data for this developmental extruded polystyrene insulation have been obtained in two laboratories using three apparatuses. A correlation of apparent thermal conductivity with time gives the thermal resistivity of the 2-in.-thick unfaced foamboards to within 3% with 95% confidence. A thermal resistivity of 30.2 m·K/W (4.36 ft²·h·°F/Btu·in.) was calculated from the correlation for time equal to 180 days after manufacture. Based on 3 years of data, the predicted thermal resistivity is

27.6 m·K/W (3.98 ft²·h·°F/Btu·in.) as time since manufacture increases. Field measurements confirm the decrease with time of the thermal resistivity that was observed in the laboratory. A three-dimensional model for heat transfer through foamboard was used to predict thermal resistivity as a function of time. A comparison of the experimental results with the model shows a radiative contribution to the total heat flux of about 30%. A one-dimensional model was used to show the effect of initial foam-gas pressure and thickness on thermal performance.

Research sponsored by the U.S. Department of Energy Office of Building and Community Systems.

Publications and
Professional
Activities

PUBLICATIONS AND PROFESSIONAL ACTIVITIES

8.1 ENERGY DIVISION ADVISORY COMMITTEE 1992

Dr. Bruce G. Buchanan

Computer Science Department
University of Pittsburgh
206 Mineral Industries Building
Pittsburgh, Pennsylvania 15260
Phone: (412) 624-9183

**Dr. Allan Hirsch
(Chairman)**

Vice President, Environmental Sciences
Director, Washington Operations
Midwest Research Institute
5109 Leesburg Pike
Suite 414
Falls Church, Virginia 22041
Phone: (703) 671-0400

Dr. Helen M. Ingram

Director, Udall Center for Studies in Public Policy
The University of Arizona
803/811 East First Street
Tucson, Arizona 85719
Phone: (602) 621-7189

Energy Division Annual Progress Report

Mr. Calvin D. MacCracken

President, Calmac Manufacturing Corporation
101 West Sheffield Avenue
P. O. Box 710
Englewood, New Jersey 07631
Phone: (201) 569-0420

Ms. Jacqueline B. Shrago

Director, Office of Technology Transfer
405 Kirkland Hall
Vanderbilt University
Nashville, Tennessee 37240
Phone: (615) 322-7056

Dr. Martin Williams

Professor, Department of Economics
Northern Illinois University
DeKalb, Illinois 60115
Phone: (815) 753-6960

8.2 ENERGY DIVISION PERSONNEL BY DISCIPLINE

[Full-time equivalents (FTEs)]

September 1992

Discipline	IAAS ^a	EEAS	CTA	ERRS	DCP	Division administration	Total (FTEs)
Technical Professionals							
Social sciences							
Anthropologists	1.0						1.0
Economists	1.0	11.5				1.0	13.5
Geographers	2.0	2.0	5.0	1.0	1.0		11.0
Planners	2.0			1.0	1.0		4.0
Political scientists	2.0						2.0
Sociologists	1.5			.5			2.0
Other	2.0						2.0
<i>Total social sciences</i>	<i>11.5</i>	<i>13.5</i>	<i>5.0</i>	<i>2.5</i>	<i>2.0</i>	<i>1.0</i>	<i>35.5</i>
Physical and life sciences							
Biologists	3.5						3.5
Chemists	1.0			1.0			2.0
Ecoiologists	1.0						1.0
Geologists	4.0						4.0
Meteorologists	2.0						2.0
Physicists	2.0			4.0			6.0
<i>Total physical and life sciences</i>	<i>13.5</i>			<i>5.0</i>			<i>18.5</i>
Engineering Sciences							
Chemical engineers	1.0		1.0	4.0			6.0
Civil engineers			4.0				4.0
Electrical engineers	1.0		1.0	3.0			5.0
Engineering physicists				1.0			1.0
Engineering scientists	1.0			2.0			3.0
Environmental engineers	1.0						1.0
Mechanical engineers	5.0			15.0		1.5	21.5
Nuclear engineers				1.0		1.0	2.0
Other				3.0			3.0
<i>Total engineering sciences</i>	<i>9.0</i>		<i>6.0</i>	<i>29.0</i>		<i>2.5</i>	<i>46.5</i>
Data Systems							
Computer sciences		1.0	2.0				3.0
Mathematicians/statisticians	1.0		6.0	1.0			8.0
Operations research			2.0				2.0
Systems analysts			1.0				1.0
Other	1.0		1.0				2.0
<i>Total data systems</i>	<i>2.0</i>	<i>1.0</i>	<i>12.0</i>	<i>1.0</i>			<i>16.0</i>
<i>Total technical professionals</i>	<i>36.0</i>	<i>14.5</i>	<i>23.0</i>	<i>37.5</i>	<i>2.0</i>	<i>3.5</i>	<i>116.5</i>
Administrative and Technical Support							
Accountants						2.0	2.0
Administrative assistants	8.0	4.0	6.0	12.0	1.0	1.0	1.0
Administrative support	4.0	1.0	4.0	8.0	1.0	7.0	38.0
Technical support							18.0
<i>Total administrative and technical support</i>	<i>12.0</i>	<i>5.0</i>	<i>10.0</i>	<i>20.0</i>	<i>2.0</i>	<i>10.0</i>	<i>59.0</i>
<i>Total</i>	<i>48.0</i>	<i>19.5</i>	<i>33.0</i>	<i>57.5</i>	<i>4.0</i>	<i>13.5</i>	<i>175.5</i>

^aIAAS = Integrated Analysis and Assessment Section; EEAS = Energy and Economic Analysis Section; CTA = Center for Transportation Analysis; ERRS = Efficiency and Renewables Research Section; and DCP = Developing Country Program.

8.3 ENERGY DIVISION PROFESSIONAL HONORS AND AWARDS FY 1992

Barnes, P. R., was elected to be a Fellow by the SUMMA Foundation for his contributions to electromagnetic pulse (EMP) analysis and development of test and protection methods for commercial power systems.

Bownds, J. M., received an *Operations and Support Award* at Martin Marietta Energy Systems Awards Night for helping to develop the Saturday Academy of Computing and Mathematics, a program for high school children and their teachers.

Brown, M. A., received an award for Distinguished Contribution to "Science Management and Policy Implementation," from American Women in Science, East Tennessee Chapter, May 1992.

Chen, F. C., received an R&D 100 Award for the *CFC/HFC Ratiometer*, a device that can identify refrigerants in a given sample and determine the concentrations present in mixed working samples, thereby aiding in the search for CFC substitutes that damage neither the environment nor equipment.

Copenhaver, E. D., along with Scott Taylor and Janet Westbrook, received a Martin Marietta Energy Systems *Significant Event Award* for development of a comprehensive ALARA (As Low As Reasonably Achievable) Radiation Protection Training Program for Engineers. This program won a national DOE TRADE TR-3 award for excellence in training and is being prepared for transfer across the DOE system.

Feldman, D. L., received a "Best of Show" award, along with D. Schaffer, W. Wilkerson, C. Shires, and B. Robinson, from the East Tennessee

Chapter of the Society for Technical Communication as Senior Editor of the *Forum for Applied Research and Public Policy*.

Harrison, I. G., received a 1992-1993 Fulbright Award on behalf of the Korean-American Educational Commission and the J. William Fulbright Foreign Scholarship Board for 10 months of lecturing in Korea.

Lee, D. W., received a Martin Marietta Energy Systems *Significant Event Award* for leading the preparation of the "SWSA 6 Performance Assessment."

MacDonald, J. M., was awarded a *Certificate of Appreciation* by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., for service as a member of Standards Committee SPC 100.5-1991, Energy Conservation in Existing Buildings-Institutional.

McCold, L. N., received the *Extra Kilometer Award* for the ANS Environmental Report for leadership in preparation of a superior environmental report, awarded by C. West, Director, Advanced Neutron Source Program.

Mei, V. C., was given a *Certificate of Recognition* for filing a patent application for the *Liquid Over-Feeding Air Condition System and Method*, an inventory that increases the efficiency, capacity, and life of automobile air conditioners.

Mei, V. C., received an *Achievement Notification* from Energy Division for being a participant in the Taiwan National Development Seminar.

Witten, A. J., received a *Certificate of Achievement* from S. K. Conver, Assistant Secretary of the Army, for the paper "High Resolution Image Processing of

Geophysical Data with Diffraction Tomography," presented at the Army Science Conference in Orlando, Florida, June 22-26, 1992.

The AMC Deployment Analysis System (ADAJS) Project team, I. Busch, S. Diegel, G. Harrison, M. Hilliard, C. Liu, and R. Solanki, received the 1992 *Applied Geography Citation Award* from the Association of American Geographers in recognition of geographical excellence for automated airlift scheduling.

The ADANS Project team also received an *Operations and Support Award* at Martin

Marietta Energy Systems Awards Night for their Automated Airlift Scheduling System, which was successfully employed during the Gulf War for the largest airlift in history.

The Nuclear Weapons Complex Reconfiguration Site (NWCERS) Proposal team, C. R. Boston, J. B. Cannon, C. W. Hagan, and others received an *Operations and Support Award* at Martin Marietta Energy Systems Awards Night for their work in preparing Volume 4 of the *Nuclear Weapons Complex Reconfiguration Site Proposal*.

8.4 ENERGY DIVISION PROFESSIONAL ACTIVITIES FY 1992

Barnes, P. R., Member, IEEE Power Engineering Society; T&D Working Group on Geomagnetic Disturbances.

Barnes, P. R., Member, International Electrotechnical Commission, Technical Subcommittee 77C, 1992 to present.

Barnes, P. R., Reviewer, *IEEE Transactions on Electromagnetic Compatibility*, 1990 to present.

Barnes, P. R., Professional Engineer registered in the state of Tennessee.

Blasing, T. J., Adjunct Associate Professor of Geography, University of Tennessee, Knoxville, 1981 to present.

Blasing, T. J., Referee, *Canadian Journal of Forest Research*, 1991.

Blasing, T. J., Referee, *National Science Foundation*, 1976 to present.

Blasing, T. J., Referee, Proposal to the National Oceanic and Atmospheric Administration, 1992.

Bownds, J. M., Invited Panel Member, First World Congress of Nonlinear Analysts, Tampa, Florida, August 1992.

Bownds, J. M., Reviewer, Department of Energy, National Science Foundation, Mathematical Reviews.

Broders, M. A., U.S. Delegate to the IEA-CADDET National Team Working Group, and Member of the IEA-CADDET U.S. National Team, 1989 to present.

Broders, M. A., U.S. Delegate to the IEA-Heat Pump Centre National Team Working Group Meeting and Member of the IEA Advanced Heat Pump U.S. National Team, 1989 to present.

Bronzini, M. S., Referee, *Transportation Research Board*, 1981 to present.

Bronzini, M. S., Referee, *Logistics and Transportation Review*, 1976 to present.

Bronzini, M. S., Chairman, Study Committee on Landside Access to U.S. General Cargo Ports, Transportation Research Board, National Research Council, 1990 to present.

Bronzini, M. S., Committee 2-39, Transportation Engineering Textbook Needs, Institute of Transportation Engineers, 1989-1992.

- Bronzini, M. S., Committee A1B01, Inland Water Transportation, Transportation Research Board, National Research Council, 1981 to present.
- Bronzini, M. S., A1B51, Task Force on Freight Transportation Data, Transportation Research Board, National Research Council, 1989 to present.
- Bronzini, M. S., Referee, *Interfaces*, 1986 to present.
- Bronzini, M. S., Civil Engineering Program Evaluator, Accreditation Board for Engineering and Technology, 1989 to present.
- Bronzini, M. S., Group 1 Council, Transportation Research Board, National Research Council, 1991 to present.
- Bronzini, M. S., Referee, *Transportation Research*, 1977 to present.
- Bronzini, M. S., Committee A3C10, Transportation of Hazardous Materials, Transportation Research Board, National Research Council, 1990 to present.
- Bronzini, M. S., Referee *Journal of the Transportation Research Forum*, 1979 to present.
- Bronzini, M. S., Referee, *Journal of Transportation Engineering*, 1980 to present.
- Bronzini, M. S., Committee A5004, Transportation Education and Training, Transportation Research Board, National Research Council, 1989 to present.
- Brown, M. A., Adjunct Associate Professor, University of Tennessee, Department of Geography.
- Brown, M. A., Editorial Boards, *Economic Geography* and *Home Energy*.
- Brown, M. A., Planning Committee, National Energy Program Evaluation Conference.
- Brown, M. A., Member Subcommittee on Conservation Verification, EPA Acid Rain Advisory Committee, 1992 to present.
- Brown, M. A., Editorial Board, *Economic Geography*, 1991-1994.
- Brown, M. A., Editorial Board, *Home Energy*, 1990-1993.
- Brown, M. A., Co-Editor, *American Association of Geographers' Energy and Environmental Specialty Group Newsletter*, 1991-1992.
- Brown, M. A., Member, Planning Committee for the 1993 National Meeting of the American Association of Geographers.
- Chen, F. C., Program Committee Member for the 6th Annual Conference on Superconductivity and Applications.
- Chen, F. C., Representative of the Energy Resources Board to the Winter Annual Meeting Committee, American Society of Mechanical Engineers (ASME).
- Chen, F. C., Proposal Reviewer for Idaho Board of Education and DOE-Small Business Innovation Research.
- Chen, F. C., Technical Session Organizer of Transportation Air Conditioning, ASHRAE SAM 1992.
- Chen, F. C., Technical Session Organizer of Heat Pump Area, IECEC 1992.
- Chen, F. C., Member-At-Large, Executive Committee, Advanced Energy Systems Division, ASME.
- Christian, J. E., ASHRAE TC 4.4 Technical Committee on Insulation and Vapor Retarder Performance, 1992.
- Christian, J. E., ASHRAE TC 4.7, Technical Committee on Energy Calculations, 1991-1992.
- Christian, J. E., Board of Directors, Building Thermal Envelope Coordinating Council, 1990-1992.
- Christian, J. E. ASHRAE 90.2P, Energy Standard for Residential Buildings, 1985-1992.
- Curlee, T. R., Municipal Solid Waste Peer Review Panel, U.S. Department of Energy, Office of Waste Reduction, 1990 to present.
- Curlee, T. R., The National Advisory Council for Environmental Policy and Technology (NACEPT), U.S. Environmental Protection Agency, Office of the Administrator.

- Curlee, T. R., Municipal Waste Advisory Committee, city of Knoxville.
- Feldman, D. L., Senior Editor, *Forum for Applied Research and Public Policy*, Energy, Environment, and Resources Center, University of Tennessee, Knoxville, 1990 to present.
- Feldman, D. L., Editorial Board, *Policy Studies Journal*, 1992 to present.
- Feldman, D. L., Executive Council, East Tennessee Chapter, American Society for Public Administration, 1992 to present.
- Feldman, D. L., Proposal Reviews for Human Dimensions of Global Change Program and Decision, Risk and Management Science Program, National Science Foundation, 1992 to present.
- Feldman, D. L., Co-Organizer, "Water Resources Strategic Planning Workshop," with Rob Turner and Dave Shriner, Environmental Sciences Division, Oak Ridge Associated Universities, August 18, 1992.
- Feldman, D. L., Referee, *The Environmental Professional*, 1990 to present.
- Feldman, D. L., Referee, *Armed Forces and Society*, 1992 to present.
- Feldman, D. L., Referee, *Global Environmental Change: Human and Policy Dimensions*, 1991 to present.
- Feldman, D. L., Referee, *Policy Sciences*, 1988 to present.
- Feldman, D. L., Referee, *Van Nostrand-Reinhold Press*, 1992 to present.
- Feldman, D. L., Referee, *Western Political Quarterly*, 1990 to present.
- Gant, K. S., Member, Federal Radiological Monitoring and Assessment Center Training Work Group, 1991 to present.
- Gant, K. S., Member, ORNL Laboratory Emergency Response Advisory Committee, 1992.
- Gant, K. S., Member, ORNL Drill and Exercise Committee, 1991 to present.
- Greene, D. L., Member, National Cooperative Highway Research Program Panel on Evaluating Alternative Methods of Highway Finance, 1992 to present.
- Greene, D. L., Member, Transportation Research Board Ad Hoc Committee on Environmental Activities, 1992 to present.
- Greene, D. L., Member, National Research Council Committee on Automobile and Light Truck Fuel Economy, 1991 to 1992.
- Greene, D. L., Chairman of Organizing Committee, Conference on Transportation and Global Climate Change, Asilomar, Calif., 1991–1993.
- Greene, D. L., Consultant, Eno Transportation Foundation, 1991 to present.
- Greene, D. L., Chairman, Transportation Research Board, National Research Council, Section F, Energy and Environmental Concerns, 1990 to present.
- Greene, D. L., Editorial Advisory Board, *Transportation Research*, 1986 to present.
- Greene, D. L., A1B51, Task Force on Freight Transportation Data, Transportation Research Board, National Research Council, 1989 to present.
- Hillsman, E. L., Member, Board of Directors, Association of American Geographers, Applied Geography Specialty Group, 1991–1992.
- Hillsman, E. L., Chair, Project Awards Competition, Association of American Geographers Applied Geography Specialty Group, 1991 to present.
- Hillsman, E. L., Member, Steering Committee for the Applied Geography Conferences, 1991 to present.
- Hirst, E., Chaired the closing panel "IRP and the Next Frontier—Conservation with the Pioneers," at NARUC's 4th National Conference on Integrated Resource Planning, Burlington, Vermont, 1992.
- Hirst, E., Member, Technical Advisory Board, The Results Center, 1992 to present.
- Hirst, E., Demand-Side Planning and Information Group, Electric Power Research Institute, 1992.

- Hirst, E., Advisory Committee, Energy Conservation Coalition, 1987 to present.
- Hirst, E., Member, Advisory Committee, Co-Chair and Co-Editor of Panel on Integrated Resource Planning for the 1992 ACEE Summer Study on Energy Efficiency in Buildings.
- Hirst, E., Member, Board of Directors, American Council for an Energy-Efficient Economy, 1992 to present.
- Hirst, E., Committee on Energy Statistics, American Statistical Association, 1992 to present.
- Hirst, E., Associate Editor, *Energy*, 1976 to present.
- Hirst, E., Member, Technical Advisory Committee, Demand-Side Management Training Institute, 1991 to present.
- Hirst, E., Member Subcommittee on Conservation Verification, U.S. Environmental Protection Agency (EPA) Acid Rain Advisory Committee, 1992 to present.
- Hirst, E., Editorial Boards, *Energy Journal*, *International Journal of Energy Systems*, *Energy Systems and Policy*, *Forum for Applied Research and Public Policy*, and *Evaluation Exchange*.
- Hu, P. S., Committee on Traffic Records and Analysis, Transportation Research Board, National Research Council, 1992-1995.
- Hu, P. S., Task Force on Statistical Methods in Transportation, Transportation Research Board, National Research Council, 1992-1995.
- Hu, P. S., Transportation Data and Information Systems Committee, Transportation Research Board, National Research Council, 1992-1995.
- Hu, P. S., 1991 YWCA Tribute to Women, Corporate Nominee, 1991.
- Hundley, A., Treasurer, Sybase International User Group, 1992 to present.
- Johnson, R. O., Member, American Society of Mechanical Engineers (ASME), 1975.
- Johnson, R. O., Member, Phi Kappa Phi Honor Society, 1977.
- Jones, D. W., Proposal Referee for National Science Foundation: Economics, Geography/Regional Science, Anthropology programs, 15 years.
- Jones, D. W., Manuscript Referee for *Annals of Regional Science* (15 years) and *Journal of Regional Science* (8 years).
- Kahn, J., International Collaboratory to the Environmental Sciences Center, University of Amazonas, 1992.
- Lee, D. W., Reviewer, *Waste Management Journal*, 1988 to present.
- Lee, D. W., Reviewer, *ASCE Journal of Hydraulics*, 1982 to present.
- Lee, D. W., Adjunct Associate Professor, North Carolina State University, Department of Mechanical and Aerospace Engineering, 1987 to present.
- Lee, D. W., Chairman, Air and Radiation Management Committee, Environmental Engineering Division, ASCE, 1991-1992.
- Lee, R., Member of Advisory Group, International Atomic Energy Agency, 1992.
- Lee, R., Member of the Editorial Advisory Board, *Energy Studies Review*, 1990 to present.
- MacDonald, J. M., Chairperson, ASTM E06.25.21, Task Group on Energy Monitoring Protocols, 1989 to present.
- MacDonald, J. M., ASHRAE TC 9.6 on Systems Energy Utilization, 1987 to present.
- MacDonald, J. M., Association of Demand-Side Management Professionals (ADSMP) Policy Subcommittee on Utility and Commercial/Industrial Interaction for Demand-Side Management, 1991 to present.
- MacDonald, J. M., ASHRAE TC 9.6 Subcommittee on Building Energy Monitoring, 1987 to present.
- MacDonald, J. M., ASHRAE SPC 100P on Energy Conservation in Existing Buildings, 1990 to present.
- McLean, R. B., National Association of Environmental Professionals (NAEP)

- Liaison to Council on Environmental Quality (CEQ) for the National NEPA Award co-sponsored by NAEP, 1992–1993.
- McLean, R. B., Co-Chairman of the NEPA Awards Committee of the NEPA Working Group, National Association of Environmental Professionals, 1992–1993.
- McLean, R. B., Founding Member of the International Design for Extreme Environments Association, Nov. 12, 1991.
- McLean, R. B., Board of Directors of the National Association of Environmental Professionals, 1992–1995.
- Mei, V. C., Elected as an officer of ASME Advanced Energy Division Heat Pump Technical Committee at 1991 ASME Winter Annual Meeting.
- Mei, V. C., Corresponding Member, ASHRAE TC 1.3, Heat Transfer and Fluid Flow Technical Committee.
- Miaou, S. P., Reviewer, *Transportation Research*, 1991–1992.
- Miaou, S. P., Reviewer, *Water Resources Research*, 1991–1992.
- Miller, R. L., Meteorology Committee Member, Air & Waste Management Association, 1992 to present.
- Mixon, W. R., Session Co-Chairman, DOE-Industry Thermal Distribution Workshop, Washington, D.C., March 29, 1992.
- Mixon, W. R., Session Chairman and Co-Chairman, Eighth Hot-Humid Climate Symposium, Dallas, May 12–14, 1992.
- Mixon, W. R., Symposium Chairman, 1992 ASHRAE Winter Meeting, Anaheim, California, January 26–29, 1992.
- Mixon, W. R., Session Co-Chairman, Affordable Comfort VI Conference, Pittsburgh, March 18–19, 1992.
- Murphy, R. W., Chairman of Magnetic Refrigeration and Applications Session at the 6th Annual Conference on Superconductivity and Applications, 1992.
- Rathi, A. K., Committee A5008, Expert Systems and Artificial Intelligence, Transportation Research Board, National Research Council, 1992 to present.
- Rathi, A. K., Secretary, Technology Subcommittee, ATMS Committee of IVHS America, 1991 to present.
- Rathi, A. K., Committee A3A11, Traffic Flow Theory, Transportation Research Board, National Research Council, 1990 to present.
- Rathi, A. K., Traffic Operations Committee, Urban Transportation Division, American Society of Civil Engineers, 1992 to present.
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- Courville, G. E., J. E. Christian, and R. S. Graves, "Thermal Conductivity of Polyisocyanurate Foam Board Insulation Blown with CFC-11 Substitutes: Laboratory and Long-Term Field Measurements," presented at the VIII Congreso Internacional de la Impermeabilización, Madrid, Spain, May 20–22, 1992.
- Curlee, T. R., and M. Russell, "Oil Vulnerability, Structural Market Changes, and the Role of the U.S. DOE," presented at a Workshop for a DOE Economic Analysis and Modeling Research. Agenda, Secretary of Energy Advisory Board, Washington, D.C., June 4, 1992.
- Davis, S. C., "Selected Statistics from the Transportation Energy Data Book," presented at the 9th Annual University of Tennessee Logistics and Transportation Alumni Symposium, Knoxville, Tennessee, November 15, 1991.
- Desjarlais, A. O., "Moisture Effects in Low-Slope Roofs," presented at the World Building Congress, Montreal, Quebec, Canada, May 18–22, 1992.
- Desjarlais, A. O., "Measurement of the Effects of Moisture on a Permeable Insulation Material," presented at the CIB 92 Conference, Montreal, Quebec, May 18, 1992.
- Desjarlais, A. O., "ORNL Roofing Research Summary," presented at the 16th Annual Federal Roofing Committee Meeting, Port Hueneme, California, February 12–13, 1992.
- Elliott, S. R., "The Problem of Optimal Rationing: An Experimental Comparison of Curtailment Mechanisms" presented at

- the Economics Seminar Series, McMaster University, Hamilton, Ontario, October 31, 1991.
- Elliott, S. R., "Marketable Emissions Rights in the Clean Air Act: An Experimental Investigation" presented at the Public Choice Society Conference, New Orleans, March 19-22, 1992.
- Elliott, S. R., J. Brown-Kruse, and W. Schulze, "The Problem of Optimal Rationing: An Experimental Comparison of Curtailment Mechanisms," presented at the University of Tennessee, Knoxville, Tennessee, April 15, 1992.
- Elliott, S. R., J. Brown-Kruse, and M. B. Cornshaw, "The Market For Tradeable Emissions Rights," presented at Public Choice Society Conference, New Orleans, March 19-22, 1992.
- Elliott, S. R., "Further Experimental Investigations Into Marketable Emissions Permit," presented at the CPR Conference, Washington, D.C., September 16-20, 1992.
- Ensminger, J. T., and R. B. McLean, "Reasons and Strategies for Improving Implementation of NEPA," presented at the 17th Annual Conference of the National Association of Environmental Professionals, Seattle, May 5-8, 1992.
- Fairchild, P. D., and S. K. Fischer, "Global Warming and End-Use Efficiency Implications of Replacing CFCs," presented at the Fourth Meeting Customer Needs with Heat Pumps Conference, Dallas, November 15-19, 1991.
- Fairchild, P. D., S. K. Fischer, and P. J. Hughes, "Total Equivalent Global Warming Impact: Combining Energy and Fluorocarbon Emission Effects," presented at the 1991 International CFC and Halon Alternatives Conference, Baltimore, December 4, 1991.
- Feldman, D. L., "On-Site Interim Storage of Spent Nuclear Fuel: Emerging Public Issues," presented at Proceedings of 3rd International High Level Radioactive Waste Management Conference, Las Vegas, April 12, 1992.
- Feldman, D. L., "Iterative Functionalism and Climate Management Regimes: From Intergovernmental Panel on Climate Change to Intergovernmental Negotiating Committee," presented at the Social Science and Environmental Impact Assessment 4th North American Symposium on Society and Resource Management, Madison, Wisconsin, May 17-20, 1992.
- Fischer, S. K., P. D. Fairchild, and P. J. Hughes, "Energy and Global Warming Impacts of CFC Alternative Technologies," presented at the Refrigeration, Energy, and Environment Symposium, Trondheim, Norway, June 23, 1992.
- Fischer, S. K., P. J. Hughes, and P. D. Fairchild, "Energy and Global Warming Impacts of CFC Alternatives Technologies," presented at the 1992 ASHRAE Annual Winter Meeting, Anaheim, California, January 26, 1992.
- Fischer, S. K., "An Analytical Screening of Alternatives for R-502 in Low-Temperature Refrigeration Applications," presented at the 1992 ASHRAE Annual Meeting, Baltimore, June 27-July 1, 1992.
- Gant, K. S., and M. V. Adler, "From Nuclides to Nerve Gas: The Development of the Chemical Stockpile Emergency Preparedness Exercise Program," presented at the 15th Annual Trade Conference, St. Petersburg, Florida, November 13-20, 1991.
- Gettings, M. B., "NEAT Overview," presented to the NY Utility Technical Advisory Committee, March 30, 1992, Albany, N.Y.
- Gettings, M. B., "Evaluation of UEMCSs Installed at the USAREUR, 222D BSB, Baumholder, Germany," presented to Baumholder Utilities personnel and

- USAREUR representatives, Baumholder, Germany, September 21, 1992.
- Gettings, M. B., and T. R. Sharp, "Weatherization Assistance Program," presented at the 1991 North Carolina State Weatherization Conference, Raleigh, North Carolina, December 2-3, 1991.
- Gettings, M. B., and T. R. Sharp, "Weatherization Assistance Program, National Energy Audit," presented at the Weatherization Assistance Program National Audit Training-DOE/HQ, Washington, D.C., November 12, 1991.
- Gettings, M. B., and T. R. Sharp, "Weatherization Assistance Program Audit Training for Atlanta Support Office," presented at the Weatherization Assistance Program National Energy Audit, Atlanta, July 6-10, 1992.
- Gibson, D. R. P., A. K. Rathi, and P. R. Surapaneni, "An Interactive Input Data Manager For The TRAF Simulation System," presented at the Fourth International Conference on Microcomputers in Transportation, Baltimore, July 22-24, 1992.
- Greene, D. L., "Automotive Fuel Economy: How Far Should We Go?" presented at the Society of Automotive Engineers, National Research Council Study on NRC Fuel Economy, Los Angeles, August 12, 1992.
- Greene, D. L., "The Costs of Oil Dependency," presented at the SAE Government Industry Meeting, Washington, D.C., April 30, 1992.
- Harrison, I. G., "Scheduling the Airlift for Operation Desert Shield and Desert Storm," presented at the East Tennessee Section of the American Association of Cost Engineers, Holiday Inn World's Fair Site, Knoxville, Tennessee, November 4-6, 1991.
- Hill, L. J., "Energy Demand Analysis for Developing Countries," presented at the Integrated Energy and Electricity Planning for Nuclear Power Seminar, Argonne National Laboratory, Argonne, Illinois, September 18, 1992.
- Hill, L. J., "Electric Utility Planning in the Caribbean: The Case of the U.S. Virgin Islands," presented at the 15th Annual Conference on Investment, Trade, and Development in the Caribbean, Miami, December 2-4, 1991.
- Hill, L. J., "The Process of Integrating DSM and Supply Resources in Electric-Utility Planning," presented at Western Area Power Administration Conservation and Renewable Energy Program Integrated Resource Planning Seminar, Sacramento, California, November 4-5, 1991.
- Hill, L. J., "DSM Programs as Part of the Electric Utility Planning Process," presented at the Western Area Power Administration Conservation and Renewable Energy Program Integrated Resource Planning Seminar, Albuquerque, New Mexico, November 19-20, 1991.
- Hill, L. J., "DSM Planning and Implementation as Part of the IRP Process," presented at the Western Area Power Administration Conservation and Renewable Energy Program Integrated Resource Planning Seminar, Sacramento, California, November 4-5, 1991.
- Hill, L. J., "Assessing Demand and Supply Resource in Electric Utility Planning," presented at the Western Area Power Administration Conservation and Renewable Energy Program Integrated Resource Planning Seminar, Albuquerque, New Mexico, November 19-20, 1991.
- Hill, L. J., "Integrated Resource Planning for Electric Utilities," presented to the Pennsylvania State Legislature, Harrisburg, Pennsylvania, December 10, 1991.
- Hill, L. J., "Aspects of Integrated Resource Planning for Electric Utilities," presented to the Energy and Natural Gas Working Committee South Carolina State

- Legislature, Columbia, South Carolina, November 6, 1991.
- Hill, L. J., "Issues in Electric-Utility Planning," presented at the Third Forum Great-Whale Conference, Montreal, Quebec, Canada, March 31–April 2, 1992.
- Hilliard, M. R., C. Liu, and I. K. Busch, "Integrating an Automated Scheduler Into a Decision Support System," presented at TIMS/ORSA Joint National Meeting, Orlando, Florida, April 29, 1992.
- Hilliard, M. R., "Introduction to ADANS," presented to the Military Airlift Command Transportation and Mobility Modeling Conference, Scott Air Force Base, Illinois, April 3, 1992.
- Hillsman, E. L., and D. R. Alvic, "Projecting Regional Patterns of Emission Allowance Trading," presented at the 1992 Annual Meeting of the Association of American Geographers, San Diego, April 19–22, 1992.
- Hillsman, E. L., "Local/Regional Policies: Acting Globally by Thinking Locally," presented at "Global Climate Change: Linking Energy, Environment, Economy, and Equity," Washington, D.C., December 5–6, 1991.
- Hillsman, E. L., and D. R. Alvic, "Conservation Measures and Emissions Allowance Trading in the Electric Utility Industry," presented at the University of Tennessee, Department of Geography Colloquium, Knoxville, Tennessee, February 27, 1992.
- Hirst, E., "Utility DSM Programs Could Cut U.S. Electricity Use One-Fifth by 2010," Presented at the Gilbert/Commonwealth Seventh Annual Executive Conference, Reading, Pennsylvania, October 2, 1991.
- Hirst, E., "Effects of Utility DSM Programs on Electricity Costs and Prices," presented at the NARUC Energy Conservation Committee, Washington, D.C., March 3, 1992.
- Hirst, E., "Key Issues in Evaluating Utility DSM Programs," presented at the Workshop on Evaluation Fundamentals for Michigan's Evaluation Collaborative, Lansing, Michigan, November 12, 1991.
- Hirst, E., "Data and Analysis Needed to Prepare an Electric-Utility Integrated Resource Plan," presented at The National Regulatory Research Institute, Columbus, Ohio, and The Clean Air Workshop, St. Louis, May 7–8, 1992.
- Hirst, E., "Demand-Side Management: Its Role in Meeting Electricity Resource Needs" presented at the Energy Forum of the City University of New York, New York City, April 22, 1992.
- Hirst, E., "The Role of Evaluation in Meeting DSM Expectations," presented at the 11th Annual Utility Energy Forum, Tahoe City, California, April 2, 1992.
- Hirst, E., "Making DSM Happen: Regulatory and Analytic Requirements," presented at the Conference on Incentive Regulation: The New Regulatory Compact, Arlington, Virginia, March 20, 1992.
- Hirst, E., "ELA's End-Use and Utility DSM Data," presented to the Committee on Energy Statistics, American Statistical Association, Washington, D.C., March 19, 1992.
- Hirst, E., "A Bright Future for Utility DSM Programs," presented at the EMA Forum on the Utility as an Instrument of Public Policy, Peachtree, Georgia, May 5, 1992.
- Hirst, E., "Definitions and Tradeoffs: Cost-Effectiveness of Utility DSM Programs," presented at the ACEEE 1992 Summer Study on Energy Efficiency in Buildings, Asilomar, California, August 30–September 5, 1992.
- Hirst, E., "Data and Analysis to Enhance the Federal Role in Improving U.S. Energy Efficiency," presented to the U.S. House of Representatives, Washington, D.C., November 6, 1991.
- Hirst, E., "Reviewing Utility Integrated Resource Plans," presented at Georgia Power, Atlanta, January 9, 1992.
- Hirst, E., "Characteristics of a Good Integrated Resource Plan," presented at

- Consolidated Edison, New York, February 26, 1992.
- Hirst, E., "DSM Risk-Reduction Strategy for Electric Utilities" and "Electric-Utility DSM Programs: A Two-Decade Growth Industry," presented at BC Hydro, Vancouver, British Columbia, August 27, 1992.
- Hirst, E., "Costs vs Prices: The Effects of Utility DSM Programs," presented at Seattle City Light, Energy Management Service Division, Seattle, August 28, 1992.
- Hu, P. S., "Trends in Household Travel Activities," presented at the 1992 Annual Meeting of the Association of American Geographers, San Diego, April 21, 1992.
- Hu, P. S., and R. Lee, "Results from the 1990 U.S. Nationwide Personal Transportation Study (NPTS)," presented at the 6th World Conference on Transportation Research, Lyon, France, June 29–July 3, 1992.
- Hughes, P. J., A. J. Occhionero, and E. A. Reid, "Absorption Chillers: Part of the Solution," presented at the 1991 International CFC and Halon Alternatives Conference, Baltimore, December 4, 1991.
- Hwang, H. L., "Estimating MDA for Low-Level Radioactivity in a Radiobioassay Laboratory," presented at the 1992 Joint Statistical Meetings, Boston, August 9–13, 1992.
- Jones, D. W., "Rural Land Use and Environmental Problems: Insights from the Thünen Model," presented at the Thünen Society 1992 Symposium, Asheville, North Carolina, August 17, 1992.
- Jones, B. K., "Modeling With FoxPro," presented at the Fourth Annual Microsoft International FoxPro Developer Conference, Phoenix, Arizona, September 19–24, 1992.
- Kahn, J. R., "The Role of Marginal Analysis and Willingness to Pay Measures in the Formulation of Environmental Policy," presented at the Southern Regional Science Association, Charleston, South Carolina, April 3–5, 1992.
- Kolb, J. O., "HUD Performance Contracting Program for Public Housing Agencies," presented at the Affordable Comfort VI Conference, Pittsburgh, March 15–20, 1992.
- Kuliasha, M. A., "Our Energy Future," presented to the Knoxville Civitan Club, Knoxville, Tennessee, April 10, 1992.
- Kuliasha, M. A., "Energy Efficient Buildings—A World of Possibilities," presented at Polmet '91 Conference and Exhibition, Kowloon, Hong Kong, December 9–13, 1991.
- Kuliasha, M. A., "Outlook for the U.S. Energy Infrastructure," presented at the Technical Society of Knoxville, Knoxville, Tennessee, March 16, 1992.
- Kyle, D. M., V. C. Mei, and F. C. Chen, "An Automobile Heat Pump Design Model," presented at the 1992 ASHRAE Annual Meeting, Baltimore, June 27–July 1, 1992.
- Kyle, D. M., "Computer Simulation of Automotive Air Conditioners," presented at the 1992 ASHRAE Annual Meeting, Baltimore, June 27–July 1.
- Lee, D. W., and D. C. Kocher, "Performance Assessment of Low-Level Radioactive Waste Disposal at Oak Ridge National Laboratory," presented at the Waste Management '92, Tucson, Arizona, March 1–5, 1992.
- Lee, R. M., "An Information Framework to Account for the External Costs of Fuel Cycles," presented at the International Atomic Energy Agency Advisory Group Meetings, Vienna, Austria, November 24–27, 1991.
- Lee, R. M., "Electricity Fuel-Cycle Externalities," presented at the 12th Annual Meeting of the International Association for Impact Assessment, Washington, DC, August 19–22, 1992.
- Lee, R. M., "Estimating the Impacts, Damages, and Benefits of Fuel Cycles: Insights From an Ongoing Study," presented at

- the Ottinger Conference, Racine, Wisconsin, September 8–11, 1992.
- Lee, R. M., "Measuring the External Costs of Fuel Cycles," presented at International Atomic Energy Agency Advisory Group Meetings, Vienna, Austria, November 20–22, 1991.
- Liu, C., and I. G. Harrison, "The Allocation of Cargo to Channel Missions," presented at the Military Airlift Command Transportation and Mobility Modeling Conference, Scott Air Force Base, Illinois, April 3, 1992.
- Liu, C., I. K. Busch, and I. G. Harrison, "An Interactive Analysis Tool for the Military Airlift Scheduling Algorithm," presented at TIMS/ORSA Joint National Meeting, Orlando, Florida, April 29, 1992.
- MacDonald, J. M., P. J. Hughes, and H. A. McLain, "Market Potential Estimates and R&D Planning for Advanced Absorption Systems for Large Commercial Buildings," presented at the ASHRAE 1992 Annual Meeting, Baltimore, June 27–July 1, 1992.
- McCold, L. N., "Decommissioning: Six Acres of Potential Impact are Evaluated," presented at Nuclear Regulatory Commission Workshop, Arlington, Virginia, November 4, 1991.
- McCold, L. N., "Solid Waste and the Clean Coal Program," presented at the Air & Waste Management Association 1992 Annual Meeting, Kansas City, Missouri, June 21–26, 1992.
- McConnell, B. W., "Potential Impact of Superconductivity on Power Quality Enhancement," presented at the Sixth Annual Conference on Superconductivity and Applications, Buffalo, September 15–17, 1992.
- McLain, H. A., "Market Potential Estimates and R&D Planning for Advanced Absorption Systems for Large Commercial Buildings," presented at the 1992 ASHRAE Annual Meeting, Baltimore, June 27–July 1, 1992.
- McLean, R. B., and L. N. McCold, "GEIS of License Renewal of Commercial Nuclear Power Plants: An Exercise in Issue Resolution," presented at NE Panel Oak Ridge National Laboratory, Oak Ridge, Tennessee, June 30, 1992.
- McLean, R. B., "Wastewater Outfall Near Field Dispersion Characteristics," presented at the NSF Workshop on Sewer Outfall Design and Water Quality Monitoring, Port Hueneme, California, June 19, 1992.
- Mei, V. C., and F. C. Chen, "Study of Thermoelectric Technology for Automobile Air Conditioners," presented at the ASME 1991 Winter Annual Meeting, Atlanta, December 1–6, 1991.
- Mei, V. C., F. C. Chen, and R. Sullivan, "Analysis of Non-CFC Automotive Air Conditioning," presented at the International CFC and Halon Alternatives Conference, Baltimore, December 3–5, 1991.
- Miaou, S., P. S. Hu, T. Wright, A. K. Rathi, and S. C. Davis, "Relationship Between Truck Accidents and Highway Geometric Design: A Poisson Regression Approach," presented at Transportation Research Annual Meetings, Washington, D.C., January 12–16, 1992.
- Miller, R. L., "The Clean Coal Program's Contributions to Addressing the Requirements of the Clean Air Act Amendments of 1990," presented at the Air & Waste Management Association 1992 Annual Meeting, Kansas City, Missouri, June 21–26, 1992.
- Mixon, W. R., "Existing Buildings Research Program," presented at the BTECC board meeting, Washington, D.C., March 2, 1992.
- Mixon, W. R., "Energy Efficient Rehab—What Works for the South," presented at the Governor's Office of Energy Resources Workshop, Decatur, Georgia, November 4–6, 1991.

- Murphy, R. W., "Magnetic Refrigeration Cycle Analysis Using Selected Thermodynamic Property Characterizations for Gadolinium Gallium Garnet," presented at the Sixth Annual Conference on Superconductivity and Applications, Buffalo, September 15-17, 1992.
- Peelle, E. B., "Public Acceptance and Public Distrust," presented at 13th Annual DOE Low-Level Waste Management Conference, Atlanta, November 19, 1991.
- Peelle, E. B., "Public Participation and Public Involvement: What Do We Know?" presented at Fulfilling the Commitment: Implementing the Letter and Spirit of NEPA, McLean, Virginia, November 21, 1991.
- Peelle, E. B., "Trust and Confidence: Some Rules of Thumb Based on 20 Years of Empirical Work in the Field," presented at the DOE Field Office, Las Vegas, May 2, 1992.
- Peelle, E. B., "Retrospective on Lessons from 1985 Tennessee MRS Attempted Siting: The Local View," presented at the American Nuclear Society Winter Meeting, San Francisco, November 10-14, 1991.
- Peelle, E. B., "Removing Barriers to Public Acceptance of Nuclear Technology and Nuclear Waste," presented at the 3rd International Conference on High Level Nuclear Waste Management, Las Vegas, April 13, 1992.
- Perlack, R. D., "Integrated Biomass Energy Systems," presented at Eco World 1992 Conference, American Society of Mechanical Engineers, Washington, D.C., June 15, 1992.
- Purucker, S. L., "Reliability-Centered Maintenance," presented at New York Power Authority Meeting, Montreal, Quebec, September 15, 1992.
- Purucker, S. L., "Reliability-Centered Maintenance," presented at the Advanced Diagnostic Workshop, sponsored by EPRI, Palo Alto, California, November 10, 1992.
- Rathi, A. K., and A. J. Santiago, "Simulation and Intelligent Vehicle Highway Systems," presented at the 3rd International Conference on Vehicle Navigation and Information Systems, Oslo, Norway, September 2-4, 1992.
- Rathi, A. J., P. DeCorla-Souza, and H. Caldwell, "Nationwide Investment Requirements for New Urban Highway Capacity Under Alternative Scenarios," presented at the 71st Annual Meeting of the Transportation Research Board, Washington, D.C., January 15, 1992.
- Rathi, A. J., M. M. Venigalla, R. Margiotta, A. Chatterjee, and D. B. Clarke, "Operational Effects of Non-Traversable Medians and Two-Way Left-Turn Lanes: A Comparison," presented at the 71st Transportation Research Board Annual Meeting, Washington, D.C., January 12-16, 1992.
- Rathi, A. J., and M. M. Venigalla, "Variance Reduction Applied to Urban Network Traffic Simulation," presented at the 71st Annual Meeting of the Transportation Research Board, Washington, D.C., January 16, 1992.
- Rathi, A. J., and M. M. Venigalla, "A Software Utility for Regional Evacuation," presented at the 8th National Conference on Computing in Civil Engineering, Dallas, June 7-9, 1992.
- Reed, R. M., R. B. McLean, S. F. Railsback, and S. Draggan, "Environmental Impact Assessment of U.S. Activities in Antarctica," presented at the 12th Annual Meeting of the International Association for Impact Assessment, Washington, D.C., August 19-22, 1992.
- Rice, C. K., "Benchmark Performance Analysis of an ECM-Modulated Air-To-Air Heat Pump with Reciprocating Compressor," presented at the ASHRAE 1992 Semi-Annual Meeting, Anaheim, California, January 26-29, 1992.

- Sand, J. R., S. K. Fischer, and P. A. Joyner, "Modeled Performance of Nonchlorinated Substitutes for CFC-11 and CFC-12 in Centrifugal Chillers," presented at the International CFC and Halon Alternatives Conference, Baltimore, December 3-5, 1991.
- Saylor, R. E., and L. N. McCold, "Bounding Analysis in NEPA Documents: When Are They Appropriate?" presented at the 17th Annual Meeting of the National Association of Environmental Professionals, Seattle, May 6-8, 1992.
- Sharp, T. R., "The National Energy Audit (NEAT) for the U.S. Department of Energy Weatherization Assistance Program," presented at the Department of Energy Regional Support Staff Training, Chicago, July 30, 1992.
- Sharp, T. R., and M. B. Gettings, "The New National WAP Energy Audit Versus Retrotech: Preliminary Results of the North Carolina Field Test," presented at the 1991 National Weatherization Conference, Baltimore, December 10-12, 1992.
- Shonder, J. A., G. Chen, and J. McEntee, "Proof of Concept of a Magnetically Coupled Stirling Engine-Driven Heat Pump," presented at the 27th Intersociety Energy Engineering Conference, San Diego, August 3-7, 1992.
- Sorensen, J. H., "Technical Support for Chemical Emergency Planning," presented at the Hazard Assessment Workshop, Estes Park, Colorado, July 9, 1992.
- Sorensen, J. H., and B. M. Vogt, "Risk Communication and Chemical Weapons," presented to the Society for Risk Analysis, Baltimore, December 8, 1991.
- Sorensen, J. H., and G. O. Rogers, "Modeling Protective Action Decisions for Chemical Weapons Accidents," presented at Proceedings of the SCS Simulation 1992 MultiConference, Orlando, Florida, April 6, 1992.
- Southworth, F., B. N. Janson, and M. M. Venigalla, "DYMODO: Towards Real Time, Dynamic Traffic Routing During Mass Evacuations," presented at Managing Risk With Computer Simulation, Orlando, Florida, April 6-9, 1992.
- Southworth, F., B. E. Peterson, J. J. Ray, H. Caldwell, and S. Lewis, "Using GIS in National Highway Network Evaluation and Design," presented at the GIS-T '92 Symposium, Portland, Oregon, March 2-4, 1992.
- Stovall, J. P., M. M. Adibi, K. A. Clements, and R. J. Kafka, "An Approach to Metering and Network Modeling," presented at the American Power Conference, Chicago, April 13-15, 1992.
- Ternes, M. P., and K. E. Wilkes, "Energy Performance and Installation Considerations for Retrofitted Exterior Masonry Wall Insulation," presented at the International Symposium on Exterior Insulation and Finish Systems, Arlington, Virginia, September 21-24, 1992.
- Tonn, B. E., R. T. Goeltz, and T. L. Chiang, "An Object-Based Interviewing System," presented at the University of Michigan Conference on Computing for the Social Sciences, Ann Arbor, Michigan, May 4-7, 1992.
- Turhollow, A. F., "Economic Considerations for the Production of Wood for Energy," presented at the First National Fuelwood Conference, Lincoln, Nebraska, November 11-12, 1991.
- Turhollow, A. F., and S. Kanhouwa, "Factors Affecting the Market Penetration of Biomass-Derived Liquid Transportation Fuel," presented at the 14th Symposium on Biotechnology for Fuels and Chemicals, Gatlinburg, Tennessee, May 11-15, 1992.
- Vineyard, E. A., and J. C. Conkling, "Flow Boiling Enhancement of R-22 and a

- Nonazeotropic Mixture of R-143a and R-124 Using Perforated Foils," presented at the 1992 ASHRAE Annual Meeting, Baltimore, June 27–July 1, 1992.
- Vineyard, E. A., "Overview of CFC Replacement Issues for Household Refrigerants," presented at the 1991 International CFC and Halon Alternatives Conference, Baltimore, December 3–5, 1991.
- Vogt, D. P., A. Daniell, S. E. Bell, "A Specific Labor Market Comparison of Male and Female Willingness to Travel: The Case of the Army National Guard," presented to the National Regional Sciences Association, New Orleans, November 8–10, 1991.
- Vogt, B. M., "Equine Evacuation Study," presented at the Hazard Research Workshop, Boulder, Colorado, July 11–15, 1992.
- Wang, J. C., "Model for Impedance of an Ionic Conductor Sandwiched Between Blocking Electrodes," presented at the Second International Symposium on Electrochemical Impedance Spectroscopy, Santa Barbara, California, July 12–17, 1992.
- White, D. L., "Reliability of Energy Conservation Resources," presented to the American Council for an Energy-Efficient Economy Summer Study, Monterey, California, August 30–September 5, 1992.
- Wilbanks, T. J., "Understanding Global Change and Sustainable Development: Challenges to Traditional Textbook Reference Materials," presented at the Annual Meeting of the National Council for Geographic Education, Santo Domingo, Dominican Republic, September 23–26, 1992.
- Wilbanks, T. J., "Human Dimensions of Energy Efficiency Improvement in Developing Countries," presented at the 27th International Geographical Congress, Washington, D.C., August 7–14, 1992.
- Wilkes, K. E., "Laboratory Measurements of Thermal Performance of Loose-Fill Attic Insulations," presented at the Affordable Comfort VI Conference, Pittsburgh, March 16–20, 1992.
- Wilkes, K. E., "History of Insulation," presented at the Iowa State Weatherization Camp, Des Moines, Iowa, September 11, 1991.
- Witten, A. J., S. S. Stevens, W. C. King, and J. Ursic, "Field Studies in Geophysical Diffraction Tomography," presented at the Workshop on Inverse Problems in Scattering and Imaging, San Diego, July 19–24, 1992.
- Witten, A. J., W. C. King, and J. Ursic, "High Resolution Image Processing of Geophysical Data with Diffraction Tomography," presented at the Army Science Conference, Orlando, Florida, June 22–25, 1992.
- Witten, A. J., and J. E. Molyneux, "Imaging Algorithms for Geophysical Applications of Impedance Tomography," presented at the Workshop on Inverse Problems in Scattering and Imaging, San Diego, July 19–24, 1992.
- Witten, A. J., and T. Levy, "New Geophysical Survey Methods Applied in Israel," seminar at Hebrew Union College, Jerusalem, Israel, June 18, 1992.
- Wolfe, A. K., "The Human Genome Project, the Public, and Risk," presented at the American Anthropological Association Annual Meeting, Chicago, November 22, 1991.
- Zaltash, A., M. R. Ally, R. L. Linkous, and L. N. Klatt, "Measurements of Heat and Mass Transfer Coefficients During Absorption of Water Vapor by Lithium Bromide and (Li, K, Na) NO₃ Mixtures," presented at the 1991 ASME Winter Annual Meeting, Atlanta, December 1–6, 1991.

Zimmerman, G. P., "The U.S. Army's
Chemical Stockpile Disposal Program and
its Environmental Impact Statements,"

presented at the Public Scoping Meeting,
Newport, Indiana, April 3, 1992.

8.8 ENERGY DIVISION CONSULTANTS AND SUBCONTRACTORS

8.8.1 Consultants

Adibi, M. M.	Lapsa, E. J.
Aspinwall, R.	Lave, L. B.
Balzer, R. A.	Leamer, E. E.
Bansal, P. K.	Lewis, T. R.
Biermann, W. J.	Lind, R. C.
Birr, D. M.	Livesay, H. C.
Bohman, R.	Lubin, N.
Bronfman, B.	Lux, D. S.
Carpenter, P. R.	Manne, A. S.
Chaney, C. S.	McCorkle, J.
Christianson, L. L.	McDonald, R. E.
Claggett, S. M.	McGimsey, M. D.
Desjarlais, A.	McIlvaine, C. M.
Epple, D. N.	Mellin, R. C.
Fitzpatrick, G. L.	Molyneux, J. E.
Franchuk, C. A.	Nadel, S. M.
Frank, A. A.	O'Hara, F. M.
Gavin, S. B.	Petrich, C. H.
Groff, G. C.	Plummer, J. L.
Grossman, G.	Poz, M. Y.
Halati, A.	Privon, G. T.
Hamilton, C. B.	Quirk, J.
Hammitt, W. E.	Raab, J. D.
Hardy, B.	Radford, C. M.
Harje, D. T.	Rothwell, G. S.
Hecht, S.	Rutherford, T. F.
Hewett, M.	Satterlee, P. E.
Hicks, E.	Shafer, S. C.
Hobson, C. S.	Sherrod, E. E.
Holzapfel, Karl-Otto	Smith, V. K.
Janson, B. N.	Smith, V. L.
Jasanoff, S. S.	Solanki, R. S.
Jones, H. G.	Suboleski, S. C.
Kaufman, G. M.	Tesche, F. M.
Kolstad, C. D.	Thompson, H. E.
Kuff, H.	Vance, E. F.
Labinov, S.	Vandergrift, L.

Walsh, T. E.
Weyant, J. P.
White, L. A.

Wilson, C. R.
Wood, R. H.
Yourstone, E. N.

8.8.2 Subcontractors by Company

American Council for an Energy-Efficient Economy (ACEEE) - Study Conference
Advanced Mechanical Technology, Inc.
Advanced Supervisory Control and Data Acquisition (SCADA) Consulting Engineers
Affordable Comfort VI Conference
American Institute of Architects/Association of the Collegiate School of Architecture (AIA/ACSA)
Albany County Opportunity, Inc.
Allied Technology Group
Alternative Energy Development, Inc.
Analysas Corporation
Applied Management Sciences, Inc.
Arthur D. Little, Inc.
Authorization Systems, Inc.
Automated Sciences Group, Inc.
Barakat & Chamberlin, Inc.
Battelle
Berkshire County Action Council
BMS Management Services
Caneta Research, Inc.
Central Vermont Community Action Council
Centro Mesoamericano De Estudios (CEMAT)
Clemson University Electric Power Research Association
Community Action Program Inner City
Crowder & Associates
Community Concepts, Inc.
Dan Hamblin & Associates, Inc.
Drexel University
Earth Ways
Economic Opportunity Research Institute
Electric Research & Management, Inc.
Electrotek Concepts, Inc.
Energetics, Inc.
Energy & Control Consultants
Energy & Environmental Analysis, Inc.
Energy Conservation Association

Energy Exchange
Ensys Energy & Systems, Inc.
Equal Opportunity Cabinet
ERCE, Environmental and Energy Service
Geophex, Ltd.
Georgia Institute of Technology
Home Energy Magazine
Housing Authority & Community Service
HRDC, District VII
Hunter College
I T Environmental Programs, Inc.
Intelligent Building Institute Foundation
International Energy Agency (IEA)
International Institute of Refrigeration
Jaycor
Knoxville College
Lawrence Berkeley Laboratory
Livingston County Weatherization
Logicon, Inc.
Lynn Economic Opportunity
Buhler & Abraham, Inc.
MacGregor-Bates, Inc.
Mantech International Corporation
Massachusetts Institute of Technology
Mechanical Technology, Inc.
Mississippi State University
Mitre Corporation
Mohawk Research Corporation
National Association of Home Builders (NAHB) National Research Center
National Association of Home Builders
National Association of Regulatory Utility Commissioners
National Association of State Utility Consumer Advocates
National Bureau of Standards
National Institute of Building Sciences
National Lighting Bureau
National Institute of Standards and Technology (NIST)

Nuclear Assurance Corporation
Oak Ridge Associated Universities
Ohio State University
Ottawa County CAA
P E A C E
PAI Corporation
Pennsylvania State University
Phillips Engineering Company
Power Technology, Inc.
Princeton University
Pueblo County Department of Community
Service
Quality Car Care, Inc.
Quantum Group, Inc.
R A Technology
R C G/Hagler Bailly, Inc.
R D G, Inc.
Research Triangle Institute
Resources for the Future
RJO Enterprises, Inc.
Rockingham County Community Action
Saturn Resource Management
Science Applications International
Corporation (SAIC)
Scranton/Lackawanna Human Development
Agency
Seda County of Governments
Self Help, Inc.
Seneca County Weatherization
Shelby County Community Service Agency
SoftTeach Corporation
South Central Community Action Program
Southern N H Services, Inc.
Southwest Foundation for Biomedical
Research
State of New York Department of Public
Service
Sterling Hobe Corporation
Stirling Technology Co.

Sunpower, Inc.
Synertech Systems Corporation
T. J. Murphy & Associates, PA
Technion Research & Development
Technology & Management Service, Inc.
Tecogen, Inc.
Tectonics Research, Inc.
Tellus Institute for Resource and
Environment
Tennessee State University
Tescor, Inc.
Test City Child Care Center
Texas A & M University
Texas Engineering Experiment Station
Thames Valley Council for Community
Action
The Production Company
The Results Group
Thomason & Associates
Tidewater Consultants, Inc.
University of Alabama
University of Arizona
University of Colorado
University of Florida
University of Maine
University of North Carolina
University of Rochester
University of Tennessee
University of Wisconsin
USSR Academy of Sciences
Vanderbilt University (Vector)
Vermont Energy Investment Corporation
Virginia Polytechnic Institute & State
University
W/L Associates
Wayne State University
WTE Corporation
Wyoming County Office for the Aging
Zaininger Engineering Company, Inc.

8.9 INVITED SPEAKERS

Date	Subject	Speaker
1991		
November 6	Assessment of TPV Technology for Heat Activated Heat Pump	<i>Mark Goldstein</i> Quantum Group Inc. San Diego, California
November 25	Hydrogen and Methanol Fuel Cell Vehicles: A Solution to Transportation Greenhouse Gas Emissions?	<i>Mark A. DeLuchi</i> Princeton University Princeton, New Jersey
1992		
February 27	Development of a Large Data-Base System for Combat Equipment Group—Europe	<i>David Paul Middendorf</i> Integrated Computer Systems Oak Ridge, Tennessee
March 9	Simulation of a Marketable Permit System for Reducing Motor Vehicle Emissions	<i>Quanlu Wang</i> Institute for Transportation Studies University of California Davis
March 9	Overview of the Federal Radiological Monitoring and Assessment Center (FRMAC)	<i>Peter G. Mueller</i> DOE Nevada Field Office Las Vegas, Nevada
March 23	Problems of Establishing an Independent Ukraine	<i>Zinoviy R. Drewnyak</i> Lviv Regional Council of People's Deputies, Ukraine and <i>Jury H. Ruban</i> Kiev Polytechnic Institute Ukraine
April 9	Modeling Heat Transfer and Moisture Migration in Partially Saturated Porous Media with a Clausius-Clapeyron-Darcy Formulation	<i>William Rust</i> Old Dominion University Norfolk, Virginia

INVITED SPEAKERS (Continued)

Date	Subject	Speaker
May 11	Soil Freezing Effect on Heat Pump Application	<i>Kiyosho Ochifuji</i> Hokkaido University Sapporo, Japan
May 11	Transmission Planning Swedish National Grid	<i>Lars Knudsen</i> Transmission Engineer Swedish National Grid
June 17	Thermally Effective, Low-Cost Foundation Systems	<i>Jan Kosny</i> University of Technology of Rzeszow, Poland
June 19	Cold Air Distribution R&D Needs: Theory and Experience	<i>Max Y. Poz</i> Moscow Scientific Research and Experimental Institute
June 24	Some Control Strategies of Radiant Floor Heating Systems	<i>Seung-Bok Leigh</i> University of Michigan Ann Arbor, Michigan
July 13	Heat Pump Application and R&D Activities in Japan, Heat and Cooling Systems Using Sewage and Rivers as a Heat Source	<i>T. Kawakami, K. Watanabe, and T. Moro</i> Heat Pump Technology Center of Japan
July 15	Numerical Analysis of the Thermal Resistance of Some Loose-Fill Insulation with Convection Occuring in the Material: Comparison with Data from the Attic Test Module	<i>Agnes Delmas</i> Bordeaux University Bordeaux, France
August 17	Complementary Use of Actual Behavior and Contingent Behavior Models	<i>Paul Mark Jakus</i> Assistant Professor The University of Tennessee Knoxville, Tennessee
August 26	UA-Based Heat Pump Model	<i>Pradeep K. Bansal</i> University of Auckland Auckland, New Zealand

INVITED SPEAKERS (Continued)

Date	Subject	Speaker
September 28	Political and Economic Programs at the CIA	<i>William K. Mills</i> Central Intelligence Agency Research and Development
September 30	A Boundary Point Algorithm for Linear Programming	<i>Chanaka P. Edirisinghe</i> Assistant Professor Management Science/Operations Research The University of Tennessee Knoxville, Tennessee

8.10 WORKSHOPS AND SYMPOSIA ORGANIZED BY ENERGY DIVISION STAFF

Appliance Research Consortium Steering Committee for AHAM CRADA, Oak Ridge, Tennessee, November 10, 1991, February 11, 1992, and May 12, 1992, organized by E. A. Vineyard.

ARI Energy Conservation Subcommittee, Oak Ridge, Tennessee, August 28, 1992, organized by V. D. Baxter.

ARI Heat Transfer Advisory Panel, Baltimore, Maryland, July 1, 1992, organized by V. D. Baxter.

ARI's R&T Energy Conservation Committee Meeting for annual industry review of BER program, Oak Ridge, Tennessee, August 19, 1992, organized by V. D. Baxter.

ASME Symposium on "Heat Pump Design, Analysis, and Application," Atlanta, Georgia, Dec. 1-6, 1991, organized by V. C. Mei.

Building Energy Efficiency Workshop, Newman, Georgia, June 8-9, 1992, organized by G. E. Courville.

CFC Coolant Replacement Strategy Review Panel in Paducah, Kentucky, July 20-22, 1992, expert participation organized by P. D. Fairchild.

CFC Foams Workshop, Oak Ridge, Tennessee, October 30-31, 1991, organized by J. E. Christian.

Conference on Economic Analysis and Modeling Related to Energy, Alexandria, Virginia, January 3-4, 1992, organized by D. J. Bjornstad.

District Heating, Cooling, and Cogeneration Workshop, Alexandria, Virginia, October 29-30, 1991, organized by M. A. Broders.

EPRI Electrical Division Committee Meeting, Oak Ridge, Tennessee, October 2, 1991, organized by S. J. Dale.

Follow-up Meeting to Workshop on Real-Time Control and Operation of Electric Power Systems, Dallas, Texas, December 10, 1991, organized by D. T. Rizy.

- Hawaii Geothermal Project Scoping Meetings, Honolulu, Hawaii, March 7-18, 1992, organized by A. K. Wolfe.
- HCFC Polyisocyanurate Insulation Joint Research Project Steering Committee, Oak Ridge, Tennessee, October 29-30, 1991, organized by J. E. Christian.
- High Voltage Direct Current (HVDC) Workshop, Portland, Oregon, May 6-8, 1992, organized by J. P. Stovall.
- Joint Research Project Steering Committee, Oak Ridge, Tennessee, October 29-30, 1991, organized by J. E. Christian.
- International Energy Agency Executive Committee on Advanced Heat Pumps, Chicago, Illinois, May 6-8, 1992, organized by M. A. Broders.
- National Intergovernmental Consultation and Coordination Board Meeting, Salt Lake City, Utah, June 14-17, 1992, organized by G. P. Zimmerman.
- 1991 Conference on Electrical Insulation and Dielectric Phenomena, Knoxville, Tennessee, October 21-23, 1991, organized by J. P. Stovall.
- 1992 IEEE International Symposium on Electrical Insulation, Baltimore, Maryland, June 7-10, 1992, organized by J. P. Stovall.
- Phillips/American Gas Cooling Center (AGCC) formation meeting of absorption heat pump commercialization consortium, St. Joseph, Michigan, February 13-14, 1992, organized by P. J. Hughes.
- S₂F₁₀ CRADA Review Meeting, Baltimore, Maryland, June 11, 1992, organized by D. R. James.
- S₂F₁₀ CRADA Review Meeting, Knoxville, Tennessee, October 24, 1991, organized by D. R. James.
- Technology Commercialization Evaluation Working Group, Washington, DC, July 6-7, 1992, organized by M. A. Brown.
- Transmission Workshop for DOE(EP)/NARUC, Lennox, Massachusetts, June 2-3, 1992, organized by D. C. Bauer.
- U.S. Army's Newport Army Ammunition Plant, Newport, Indiana; Public Meeting for the Site-Specific EIS for the CSDP, Newport (Cayuga), Indiana, April 3, 1992, organized by T. G. Patton.
- U.S. DOE's Des Moines Energy Center Public Scoping, Pleasant Hill, Iowa, July 8-9, 1992, organized by R. L. Miller.
- Workshop for Fuel Cells in Residential and Small Commercial Applications, Ellicott City, Maryland, July 9-10, 1992, organized by F. C. Chen.
- Workshop on Real-Time Control and Operation of Electric Power Systems, Denver, Colorado, November 19-21, 1991, organized by D. T. Rizy.

8.11 ENERGY DIVISION SPONSORS, EXPENDITURES, AND COMMITMENTS OF SCIENTIFIC STAFF FOR FY 1992

Sponsor	Expenditures ^a (\$10 ³)	Scientific staff (person-years)		Direct person- year costs ^c (\$10 ³)	Subcontract costs with overhead ^d (\$10 ³)
		Energy Division	Other Divisions ^b		
Department of Energy work					
Assistant Secretary for Conservation and Renewable Energy					
AK-Electric Energy Systems	2,294	3.8	0.1	661	1,882
AM-Geothermal	886	3.5	0.5	554	187
EB-Solar Energy	230	1.4	0.0	141	26
EC-Buildings and Community Systems	11,004	24.0	0.9	3,860	5,338
ED-Industrial Energy Conservation	347	1.3	0.4	271	(8)
EE-Transportation	618	1.8	0.1	298	230
EF-State/local programs	1,825	5.6	0.0	913	687
EK-Utility Sector	1,166	2.8	0.0	468	435
KK-Utility Sector	8	0.0	0.0	7	0
<i>Subtotal</i>	<i>19,008</i>	<i>44.2</i>	<i>2.0</i>	<i>7,173</i>	<i>8,777</i>
Office of Civilian Radioactive Waste Management					
DB-Nuclear Waste and	60	0.0	0.0	4	57
<i>Subtotal</i>	<i>60</i>	<i>0.0</i>	<i>0.0</i>	<i>4</i>	<i>57</i>
Assistant Secretary for Defense Programs					
GE-Materials Production	49	0.2	0.0	39	0
<i>Subtotal</i>	<i>49</i>	<i>0.2</i>	<i>0.0</i>	<i>39</i>	<i>0</i>
Office of Environmental Restoration and Waste Management					
EW-Environmental Restoration and Waste Management—Defense	181	0.4	0.1	76	81
<i>Subtotal</i>	<i>181</i>	<i>0.4</i>	<i>0.1</i>	<i>76</i>	<i>81</i>
Energy Information Administration					
TA-National Energy Information System	777	1.7	0.0	254	461
<i>Subtotal</i>	<i>777</i>	<i>1.7</i>	<i>0.0</i>	<i>254</i>	<i>461</i>
Office of Energy Research					
KC-Basic Energy Sciences	407	1.1	0.7	268	0
KD-Energy Research Analysis	225	1.0	0.0	71	42
<i>Subtotal</i>	<i>632</i>	<i>2.1</i>	<i>0.7</i>	<i>339</i>	<i>42</i>
Federal Energy Regulatory Commission					
VR-Federal Energy Regulatory Commission	809	2.6	0.6	526	82
<i>Subtotal</i>	<i>809</i>	<i>2.6</i>	<i>0.6</i>	<i>526</i>	<i>82</i>

ENERGY DIVISION SPONSORS, EXPENDITURES, AND COMMITMENTS OF SCIENTIFIC STAFF FOR FY 1992 (Continued)

Sponsor	Expenditures ^a (\$10 ³)	Scientific staff (person-years)		Direct person- year costs ^c (\$10 ³)	Subcontract costs with overhead ^d (\$10 ³)
		Energy Division	Other Divisions ^b		
Assistant Secretary for Fossil Energy					
AA-Coal	36	0.2	0.0	35	0
AC-Petroleum	128	0.2	0.1	66	54
AZ-Innovative Clean Coal Technology	331	1.2	0.2	241	0
SA-Strategic Petroleum Reserve	233	1.1	0.0	189	10
<i>Subtotal</i>	<i>728</i>	<i>2.7</i>	<i>0.3</i>	<i>531</i>	<i>64</i>
Assistant Secretary for International Affairs and Energy Emergencies					
NB-Emergency Preparedness	98	0.2	0.0	28	58
<i>Subtotal</i>	<i>98</i>	<i>0.2</i>	<i>0.0</i>	<i>28</i>	<i>58</i>
Assistant Secretary for Nuclear Energy					
AF-Nuclear Energy R&D	56	0.0	0.0	6	0
CD-Uranium Enrichment	125	0.0	0.0	0	0
<i>Subtotal</i>	<i>181</i>	<i>0.0</i>	<i>0.0</i>	<i>6</i>	<i>0</i>
Office of Policy, Planning and Analysis					
PE-Policy, Planning and Analysis	2,232	5.9	2.0	1,278	919
<i>Subtotal</i>	<i>2,232</i>	<i>5.9</i>	<i>2.0</i>	<i>1,278</i>	<i>919</i>
DOE Related Projects					
Allied Signal	205	0.9	0.3	185	6
Bonneville Power Administration	816	1.6	0.3	319	93
EG&G	2	0.0	0.0	2	0
K-25	237	1.0	0.2	122	50
Lawrence Berkeley Laboratory	2	0.0	0.0	2	0
National Renewable Energy Laboratory	132	0.4	0.0	78	41
Oak Ridge Associated Universities	42	0.2	0.0	34	0
Oak Ridge Operations	15	0.0	0.0	8	0
Paducah	247	1.8	0.0	180	0
Portsmouth	90	0.8	0.0	70	0
Rocky Flats	86	0.1	0.3	71	0
Sandia National Laboratory	53	0.1R0.2	0.0R0.0	20	15
University of Tennessee	20			14	0
<i>Subtotal</i>	<i>1,947</i>	<i>7.1</i>	<i>1.1</i>	<i>1,105</i>	<i>205</i>
Total DOE Work	26,702	67.1	6.8	11,359	10,746

ENERGY DIVISION SPONSORS, EXPENDITURES, AND COMMITMENTS OF SCIENTIFIC STAFF FOR FY 1992 (Continued)

Sponsor	Expenditures ^a (\$10 ³)	Scientific staff (person-years)		Direct person- year costs ^c (\$10 ³)	Subcontract costs with overhead ^d (\$10 ³)
		Energy Division	Other Divisions ^b		
Other federal agencies work					
Department of Defense					
Department of the Air Force					
Engineering & Services Command	439	0.8	0.1	148	241
Logistics Command	65	0.3	0.0	56	0
Military Airlift Command	3,334	3.5	0.0	480	2,063
Shaw Air Force Base	34	0.1	0.0	18	11
Space Division	28	0.0	0.0	5	12
Tactical Air Command	5	0.0	0.0	6	0
Tyndall Air Force Base	90	0.0	0.0	0	89
U.S. Transcom	779	1.8	0.0	261	322
Subtotal	4,774	6.5	0.1	974	2,738
Department of the Army					
Army	126	0.6	0.0	94	0
Army-Europe	118	0.3	0.0	64	0
Belvoir	31	0.2	0.0	34	0
Construction Engineering Research Laboratory	13	0.1	0.0	12	0
Facilities Engineering Support Agency	236	0.1	0.0	20	202
Forces Command	48	0.2	0.0	41	3
Tank Automotive Command	37	0.2	0.0	35	0
Toxic & Hazardous Materials Agency	3,645	7.9	2.3	1,636	706
Subtotal	4,254	9.6	2.3	1,936	911
Department of the Navy					
Marine Corps	(9)	0.0	0.0	0	(9)
Military Sealift Command	163	0.0	0.0	0	0
Naval Research	93	0.3	0.0	58	22
Naval Sea System Command	(40)	0.0	0.0	0	(49)
Subtotal	207	0.3	0.0	58	(36)
Joint Agencies					
Defense Communications Agency	41	0.2	0.0	35	0
Defense Nuclear Agency	145	0.6	0.0	102	27
Military Traffic Management Command	450	1.1	0.0	143	158
National Guard Bureau	292	0.4	0.0	78	114
Subtotal	928	2.3	0.0	358	299
Subtotal DOD Work	10,163	18.7	2.4	3,326	3,912

ENERGY DIVISION SPONSORS, EXPENDITURES, AND COMMITMENTS OF SCIENTIFIC STAFF FOR FY 1992 (Continued)

Sponsor	Expenditures ^a (\$10 ³)	Scientific staff (person-years)		Direct person- year costs ^c (\$10 ³)	Subcontract costs with overhead ^d (\$10 ³)
		Energy Division	Other Divisions ^b		
Bureau of the Census	7	0.0	0.0	3	3
Bureau of Labor Statistics	81	0.2	0.0	44	24
Bureau of Mines	30	0.0	0.0	1	10
Council on Environmental Quality	2	0.0	0.0	2	0
Department of Agricultural	2	0.0	0.0	2	0
Department of State-AID	572	2.3	0.1	361	31
Department of Transportation-PHWA	1,374	4.3	0.5	792	323
Department of Transportation-Volpe	20	0.1	0.0	12	0
Environmental Protection Agency	102	0.1	0.0	22	52
Federal Emergency Management Agency	2,013	4.0	0.2	679	789
National Park Service	240	0.9	0.1	142	65
National Science Foundation	106	0.3	0.1	76R396	0
Nuclear Regulatory Commission	558	2.2	0.5	21	7
Tennessee Valley Authority	44	0.1	0.0		21
Total Other Federal Agencies Work	15,314	33.2	3.9	5,879	5,237
Private organizations work					
CISEP	(10)	0.0	0.0	0	0
Commonwealth Electric	140	0.8	0.0	134	0
Electric Power Research Institute	109	0.5	0.0	91	(3)
Foamseal	9	0.1	0.0	9	0
Gas Research Institute	302	1.0	0.0	133	89
New York State Energy R&D Authority	30	0.1	0.0	20	15
Society of the Plastics Industry	42	0.3	0.0	42	0
TAMS Consultants, Inc.	147	0.5	0.0	72	58
University of Tennessee	38	0.2	0.0	32	6
Total private organizations work	807	3.5	0.0	533	165
Total non-DOE work	16,121	36.7	3.9	6,412	5,402
Total DOE work	26,702	67.1	6.8	11,359	10,746
Total Energy Division work	42,823	103.8	10.7	17,771	16,148

^aThe difference between total expenditures (column 2) and the sum of columns 5 and 6 is money spent on computer, programmer, and analyst support from Computer Services; travel; material purchases; technical information services; P&E, I&C; etc.

^bIncludes the following research divisions: Analytical Chemistry, Applied Technology, Chemical Technology, Engineering Physics and Mathematics, Engineering Technology, Environmental Sciences, Health and Safety Research, Metals and Ceramics, and Research Reactors.

^cIncludes technical staff labor costs for Energy Division and other research divisions and Laboratory overhead @ 47.5%.

^dIncludes Laboratory overhead @ 47.5% for onsite services and the subcontract surcharge @ 8.6% for off-site services. The subcontract surcharge is to pay for the costs of accounts payable, auditing, and accounting.

ENERGY DIVISION

AUGUST 1992

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ASSOCIATE DIRECTOR
EDWARDS

ASSOCIATE DIRECTOR
PARHAM

ADMINISTRATIVE ASSISTANT
C. MYERS

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S. B. WRIGHT
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P. C. GAILEY¹³

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D. B. WADDLE¹²

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