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MARTIN MARIETTA

Energy Division Annual Progress Report for Period Ending September 30, 1986

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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ENERGY DIVISION ANNUAL PROGRESS REPORT for Period Ending September 30, 1986

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MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Contents

Acronyms

AACE	–	Athens Automation and Control Experiment
ADM	–	Action Description Memorandum
ADP	–	automated data processing
AFESC	–	Air Force Engineering and Services Center
AFWIS	–	Air Force World Wide Military Command and Ccntrol System Information System
AI	–	artificial intelligence
AID	–	Agency for International Development
ARK	–	Acquisition of and Reasoning about Knowledge
ASE	–	Alliance to Save Energy
ASHRAE	–	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	–	American Society for Testing and Materials
AUB	–	Athens Utilities Board
BER	–	Building Equipment Research
BOS	–	Base Operating Support
BPA	-	Bonneville Power Administration
BTESM	–	Building Thermal Envelope Systems and Materials
C&TD	–	Computing and Telecommunications Division
CACS	–	Commercial and Apartment Conservation Service
CAI	–	computer-aided instruction
CCMHP	–	continuously capacity modulated heat pump
CFC	–	chlorofluorocarbons
CGE	–	computable general equilibrium
CHP	–	chemical heat pump
CIVPERCEN	–	U.S. Army Civilian Personnel Center
CLP	–	current-limiting protector
COP	–	coefficient of performance
CRBED	–	Commercial Reference Building Energy Demand
DARPA	–	Defense Advanced Research Projects Agency
DAS	–	Data and Analysis Section
DBMS	–	data base management system
DEC	–	Digital Equipment Corporation
DES	–	decision support system
DM6TP	–	Data Management 6 Transaction Processing
DMETEG	–	dimethyl ether of tetraethylene glycol
DMG	–	Data Methods Group
DNA	–	Defense Nuclear Agency
DOD	–	U.S. Department of Defense
DOE	–	U.S. Department of Energy
DOS	–	disk operating system
DOT	–	U.S. Department of Transportation
DSRD	–	Data Systems Research and Development Program
DSRS	–	Decision Systems Research Section
DSS	–	decision support system

DTNSRDC	–	David Taylor Naval Ship R&D Center
DX	–	direct expansion
ECIP	–	Energy Conservation Investment Program
ECUT	–	Energy Conversion and Utilization Technologies
EIA	–	Energy Information Administration
EIR	–	Economic Impact Region
EIS	–	environmental impact statement
EMP	–	electromagnetic pulse
EPA	–	Environmental Protection Agency
EPPD	–	Energy Planning and Policy Development
EPRI	–	Electric Power Research Institute
ERIP	–	Energy-Related Inventions Program
ERR	–	Efficiency and Renewables Research Section
ETC	–	Energy Technology Center
FE	–	Fossil Energy
FEMA	–	Federal Emergency Management Agency
FERC	–	Federal Energy Regulatory Commission
FETEP	–	Fossil Energy Technology Environmental Program
FFT	–	fast Fourier transform
FHWA	–	Federal Highway Administration
FMPC	–	Field Material Production Center
FORPS	–	Forth-based production system
FPSE	–	free-piston Stirling engine
FY	–	fiscal year
GAX	–	general-absorber heat exchange
GCHP	–	ground-coupled heat pump
GEIS	–	generic environmental impact statement
GPU	–	General Public Utilities
GRI	–	Gas Research Institute
HDM	–	Hedonic Demand Model
HHS	–	U.S. Department of Health and Human Services
HMCHP	–	Heat-of-Mixing Chemical Heat Pump
HOB	–	height of burst
HOV	–	high-occupancy vehicle
HUD	–	U.S. Department of Housing and Urban Development
HVAC	–	heating, ventilating, and air conditioning
HWGWTF	–	Hazardous Waste Ground Water Task Force
IASS	–	Integrated Analysis and Assessment Section
IC	–	internal combustion
IEEE	–	Institute of Electrical and Electronic Engineers
IEF	–	Information Engineering Facility
IHP	–	Industrial Heat Pump Program
IMEASY	–	Integrated Management and Economic Analysis System
IOU	–	investor-owned utility
ISTF	–	Ice Storage Test Facility

ITIS	–	Integrated Technical Information System
ITO	–	Installation Traffic Office
JTLS	–	Joint Theater Level Simulation
KSC	–	Kennedy Space Center
LAN	–	local area network
LBL	–	Lawrence Berkeley Laboratory
LCCM	–	Least Cost Mix Model
LES	–	linear expenditure system
LISP	–	list processing
LLW	–	low-level waste
LSCS	–	Large Scale Climate Simulator
LeRC	–	Lewis Research Center
MIS	–	management information system
MNL	–	multinomial logit model
MTI	–	Mechanical Technology, Inc.
MTMC	–	Military Traffic Management Command
NAHB	–	National Association of Home Builders
NALC	–	Naval Aviation Logistics Center
NARDAC	–	Naval Regional Data Automation Center
NARM	–	nonazeotropic refrigerant mixtures
NASA	–	National Aeronautics and Space Administration
NATAS	–	National Appropriate Technology Assistance Service
NAVMASSO	–	Navy Management System Support Office
NAVMIS	–	Navy Manpower Information System
NAVSEA	–	Naval Sea Systems Command
NBECS	–	Nonresidential Buildings Energy Consumption Survey
NBS	–	National Bureau of Standards
NCPDS	–	Navy Civilian Personnel Data System
NEPA	–	National Environmental Policy Act
NMPC	–	Naval Military Personnel Command
NRC	–	Nuclear Regulatory Commission
NRL	–	Naval Research Laboratory
OARS	–	OSTI Automated Retrieval System
OBCS	–	Office of Buildings and Community Systems
OEA	–	Office of Environmental Analysis
OFT	–	Operational Flight Trainers
OGSST	–	Office of Oil, Gas, Shale, and Special Technologies
ORGDP	–	Oak Ridge Gaseous Diffusion Plant
ORNL	–	Oak Ridge National Laboratory
ORO	–	Oak Ridge Operations
OSTI	–	Office of Scientific and Technical Information
OSWER	–	Office of Solid Waste and Emergency Response
OTS	–	Office of Transportation System
PC	–	personal computer
PEAC	–	Power Electronics Application Center

PM-ECM	–	permanent magnet electronically commutated motor
PNL	–	Pacific Northwest Laboratory
PSA	–	Problem Statement Analyzer
PSL	–	Problem Statement Language
PSTP	–	Power Systems Technology Program
PUC	–	public utility commission
PWF	–	permanent wood foundation
QMDS	–	Quantitative Methods and Decision Support Group
R&D	–	research and development
RCCP	–	Residential and Commercial Conservation Program
RCRA	–	Resource Conservation and Recovery Act
RCRIS	–	Resource Conservation and Recovery Information System
RCS	–	Residential Conservation Service
RECAP	–	Residential Energy Conservation Action Program
RECON	–	Remote Console
REE	–	Resource and Environmental Economics
RF	–	radio frequency
RMS	–	root mean square
RTRA	–	Roof Thermal Research Apparatus
RWP	–	Residential Weatherization Program
SAC	–	Strategic Air Command
SAIL	–	Scheduling Algorithm to Improve Lift
SDS	–	Source Data System
SERI	–	Solar Energy Research Institute
SFC	–	Synthetic Fuels Corporation
SIR	–	savings-to-investment ratio
SNAP	–	Shipboard Non-tactical ADP Program
SOTACA	–	State-of-the-Art Contingency Analysis
SPR	–	Strategic Petroleum Reserve
SRC	–	Synergic Resource Corporation
STAFS	–	Standard Automated Financial System
SUAD-RT	–	Shipboard Uniform Automated Data Processing System—Real Time
SYSRAP	–	System Reconfiguration and Analysis Program
T/C	–	transmission/compressor
TAHP	–	thermally activated heat pumps
TASS	–	Technology and Social Systems
TFMMS	–	Total Force Manpower Management System
TFR	–	trifluoroethanol
TMI-1	–	Three Mile Island-1
TOFACS	–	Technical Office Automation and Communications System
TOPS	–	Transportation Operational Personal Property Standard System
TVA	–	Tennessee Valley Authority
USAF	–	U.S. Air Force
UV	–	ultraviolet
VHLL	–	very high level languages

VITA	–	**Volunteers in Technical Assistance**
WAP	–	**Weatherization Assistance Program**
WSHP	–	**water-source heat pump**
WWMCCS	–	**World Wide Military Command and Control System**

Abstract

This report describes work done by staff of the Energy Division of Oak Ridge National Laboratory during FY 1986. The work of the Division is quite diversified, but it can be divided into four research themes: (1) technology for improving the productivity of energy use; (2) technology for electric power systems; (3) analysis and assessment of energy and environmental issues, policies, and technologies; and (4) data systems research and development (R&D). The research is supported by the U.S. Department of Energy (DOE), numerous other federal agencies, and some private organizations.

During FY 1986, work on technologies for improving the productivity of energy use focused on heat pumps and buildings. Advanced absorption and engine-driven heat pumps being developed by various companies demonstrated coefficients of performance (COPs) from 1.6 to 2.1 at 8.3°C for heating and from 0.8 to 1.1 at 35°C for cooling; however, a new absorption concept promises COPs for heating and cooling of 3 and 2, respectively. In the buildings area, detailed design of the Large Scale Climate Simulator for experimenting with roof systems was completed, and a new method for field determination of the thermal resistance of roofs was developed and recommended to the American Society for Testing and Materials as a standard method. A procedure for calculating optimum foundation insulation was devised and suggested to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. A radiant barrier (aluminum foil) laid on top of attic insulation (R-19) was shown to save 17% of seasonal cooling load and 10% of seasonal heating load in unoccupied houses in Knoxville, Tennessee.

Power systems research is concerned primarily with technology for electricity transmission and distribution. During FY 1986, the Automation and Control Experiment, conducted in collaboration with the Athens Utility Board in Athens, Tennessee, showed the value of high-speed data acquisition for understanding volt/var changes and load control strategies and for developing more accurate simulation models. Early results from a program to assess the impact on the electric grid of electromagnetic pulse from high-altitude nuclear explosions indicate that surges with over 1-MW peak voltage and a variety of pulse shapes can result and that these may have a high probability of damaging insulation systems. Technical assistance to the National Association of Home Builders Research Foundation resulted in the adoption of an addition to the National Electric Code permitting the use of Smart-House wiring concepts (closed-loop power).

The analysis and assessment area includes work on energy and resource issues, environmental issues, and emergency preparedness/response. During FY 1986, the effectiveness of utility and government energy conservation programs in various parts of the country was measured; results showed that success is highly dependent on local and regional conditions as well as program design and implementation. Eric Hirst was lead author of a book, *Energy Efficiency in Buildings: Progress and Promise*, which was published during FY 1986. The DOE Energy-Related Inventors Program was evaluated showing that sales from program inventions have been well over $200 million, which is 18 times the value of government grants supporting these inventions. The added costs of energy

efficiency improvements to automobiles since the late 1970s were found to be approximately equal to the estimated consumer surplus resulting from these changes. Studies for the Agency for International Development resulted in an equilibrium model for the economy of Haiti, an estimate of the impact of crude oil price increases on the debt of African non-oil-producing countries, examination of the substitution of coal briquettes for charcoal in several countries, and design and evaluation of a transportation energy conservation program in Costa Rica.

Several complicated environmental impact statements (EISs) were completed, including a final EIS for the Federal Energy Regulatory Commission concerning proposed small hydroelectric projects in the Owens Valley of California and a draft programmatic statement for the U.S. Army on the Chemical Stockpile Disposal Program.

A regional modeling and data analysis framework was developed for the Federal Emergency Management Agency to assess the economic consequences of disasters anywhere in the country, and a series of state-of-the-art studies was completed on topics ranging from warning systems to postdisaster economic recovery. Other emergency preparedness research completed included estimating (1) the availability of mobility fuels for the U.S. Navy during petroleum supply disruptions and (2) the vulnerability of electricity transmission and oil and gas pipelines to loss of critical components.

During FY 1986, data systems R&D aimed at techniques for improving decision making in large public organizations. An analysis was completed for the U.S. Environmental Protection Agency suggesting a distributed two-domain data system for the Resource Conservation and Recovery Act Information System, and a microcomputer-based groundwater workstation was developed to assist in the evaluation of commercial hazardous waste sites. An optimizing algorithm was developed for the Military Sealift Command to convert information about cargo ships, ports, and required destination times into detailed routes and cargo schedules. Advanced software engineering techniques that were completed with a state-of-the-art relational data base management system are being used to develop better tools for operating the U.S. Department of Defense personal property transportation system. Finally, research was initiated on advancing the state of expert systems for automation of knowledge acquisition and machine learning using genetic algorithms and classifier techniques.

An important aspect of all the work is research utilization. This obligation was pursued by engaging private sector firms in research so that technology, as it is developed, will be more easily commercialized; by holding workshops and symposia; by interacting with representatives of state and local governments; by staff involvement in professional and trade organizations; and, of course, by publishing the results of research in journals, reports, and other media.

1. Introduction and Executive Summary

William Fulkerson

B. G. Arrington	T. D. Ferguson	T. J. Murphy
C. T. Badger	M. T. Huie*	K. R. Spence*
B. T. Edwards	L. M. Johnson	J. E. White

1.1 INTRODUCTION

The Energy Division is one of fifteen research divisions at Oak Ridge National Laboratory (ORNL). It was established in 1974 to bring together (1) work on environmental, technological, and regional assessments related to energy development and (2) research on energy demand analysis and on improving the efficiency of energy use and conversion (energy conservation). More recently, data systems research and development (DSRD) has become an important and growing new area. DSRD is concerned with developing computer based tools and methods useful for improving decision making and operational efficiency of large public organizations. Because of this broad scope, the staff of the Division has always been multidisciplinary. By the end of FY 1986, the staff of scientific and technical professionals numbered 171, including 64 engineers, 27 physical and life scientists, 37 data systems specialists, and 42 social scientists. The Division is the "home" for most of the practicing social scientists at ORNL, including economists, geographers, political scientists, sociologists, anthropologists, psychologists, planners, demographers, and others. In addition, there is a growing number of guest scientists, consultants, and graduate students in various disciplines contributing to Energy Division projects.

The work of the Division is carried out not only by its own staff but also by subcontractors and colleagues in many other ORNL divisions, including Environmental Sciences, Health and Safety Research, Biology, Environmental and Occupational Safety, Instrumentation and Controls, Engineering Technology, Metals and Ceramics, Analytical Chemistry, Solid State, Fusion Energy, Fuel Recycle, and Chemical Technology. Important contributions were also made by the staff of Computing and Telecommunications, Information Resources, and Engineering, which are Martin Marietta Energy Systems-wide organizations. During FY 1986, more than one-half of the budget was spent by subcontractors, including a large number of universities and private firms. The list of subcontractors (Sect. 8.7) shows the range of institutions involved. One of the major roles of the Energy Division, therefore, is to manage large or complicated projects that require mobilization of talent from various sources within and outside the Division.

*Finance and Materials Division.

This twelfth annual report of the Division covers work done during FY 1986 (October 1, 1985, through September 30, 1986). During the year, some important organizational changes were made in the Division. The most significant of these was the appointment of two new section heads. Michael A. Kuliasha was selected to head the Efficiency and Renewables Research Section after the death of John Michel in April 1986. Also, Johnnie B. Cannon was chosen to replace Bud Zittel as head of the Integrated Analysis and Assessment Section following Zittel's announcement of his intention to retire early in 1987. The leadership of the other three sections of the Division remains unchanged: the Energy and Economic Analysis Section is headed by Bob Shelton; the Data and Analysis Section is headed by George A. Dailey; and the Decision Systems Research Section is headed by Robert B. Honea. Chapters 2 through 6 summarize the activities of each of the sections of the Division; and Chap. 7, Integrated Programs, reports work on a variety of topics that cut across section lines. These integrated programs are under the supervision of Thomas J. Wilbanks, Associate Director of the Division. It should be emphasized, however, that many projects managed by people within the various sections also transcend section and Division boundaries. The organization of the Division, as of August 1986, is shown at the end of Chap. 8.

In FY 1986, the Division grew in both staff and budget. Expenditures rose about 54% compared with FY 1985, and the total staff grew from 214 people at the end of FY 1985 to 235 at the end of 1986. The research efforts were supported primarily by the U.S. Department of Energy (DOE), but also by many other federal agencies, principal among them the U.S. Department of Defense (DOD). DOD projects included work for the Departments of the Army, Air Force, and Navy; for the Marine Corps; and for a number of joint agencies, such as the Military Traffic Management Command, the Military Sealift Command, the Military Airlift Command, and the Office of the Joint Chiefs of Staff. Important support also came from the U.S. Nuclear Regulatory Commission (NRC), the U.S. Agency for International Development (AID), the Federal Emergency Management Agency (FEMA), the U.S. Environmental Protection Agency (EPA), the Tennessee Valley Authority, the National Aeronautics and Space Administration, the U.S. Customs Service, and the Departments of Transportation, Justice, Labor, and Education. Within DOE, support came from six assistant secretaries (Conservation and Renewable Energy; Fossil Energy; Defense; Nuclear Energy; Environment, Safety and Health; and International Affairs and Energy Emergencies) and also from the Energy Information Administration (EIA); the Office of Energy Research; the Federal Energy Regulatory Commission (FERC); the Office of Policy, Planning and Analysis; the Oak Ridge Operations Office (ORO); the Bonneville Power Administration (BPA); the Office of Scientific and Technical Information; and the Strategic Petroleum Reserve. Work was also supported by the Electric Power Research Institute (EPRI), the Pacific Power and Light Company, the Puget Sound Power and Light Company, Borg-Warner Corporation, and the National Association of Homebuilders. A summary of expenditures for each sponsor is given in Sect. 8.11.

1.2 TECHNICAL ACTIVITIES AND ACCOMPLISHMENTS

The work of the Division is very diversified, but it can be divided into four major themes: (1) technology for improving the productivity of energy use; (2) technology for electric power systems; (3) analysis and assessment of energy and environmental technologies, issues, and policies; and (4) data systems research and development. Some significant accomplishments in each of these four theme areas are summarized in the remainder of this section. Each item includes a reference to the relevant section in the body of the report.

I. TECHNOLOGY FOR IMPROVING THE PRODUCTIVITY OF ENERGY USE

Research on improving the efficiency and productivity of energy end use is focused primarily on buildings. Work on heat pumps, including electric-driven as well as heat-activated systems, is a specialty. It includes applications ranging from heating and cooling residential and commercial buildings to amplifying heat or boosting the temperature of heat used in industrial processes. Research is also under way on improving building thermal envelopes, with emphasis on walls, low-slope roofs, foundations, and materials. In addition, ORNL is helping DOE carry out research to identify and develop cost-effective retrofit conservation measures to upgrade the existing stock of buildings. Highlights are as follows:

A. Heat Pumps

- A patent application was filed by DOD for an advanced absorption heat pump cycle devised by an Energy Division staff member. Analysis indicates the cycle should be 30–50% more efficient than the best existing double-effect absorption chillers. This performance should be possible using less heat exchanger area than current state-of-the-art double-effect absorption machines. (Sect. 4.1.1)

- A patent was also filed by DOE on a unique fiber optics instrument for measuring in real time the fluid concentrations in absorption machines. The instrument was developed by the ORNL Analytical Chemistry Division and is described in the FY 1985 Annual Report.[1] (Sect. 4.1.1)

- Technion Institute of Technology of Israel, under subcontract, developed and validated an absorption heat pump simulation model.[2] The model can be used to evaluate proposed new cycles of any complexity or configuration. (Sect. 4.1.1)

- Two sets of high-temperature working fluid pairs for industrial absorption heat pumps were identified, one by the Desert Research Institute of the University of Nevada[3] and the other by Energy Concepts Company of Annapolis, Maryland.[4] These fluids are stable to 250°C and show promise for significantly expanding the range of applicability for industrial processes. (Sect. 4.1.2)

- Tectonics Research, Inc., under subcontract, successfully tested the Braun linear internal-combustion engine-driven heat pump using natural gas as a fuel. A cooling coefficient of performance (COP) of 1.1 at 35°C (95°F) and a heating COP of 2.1 at 8.3°C (47°F) were achieved. The bellows seal assembly (by Metal Bellows, Inc.) between the engine and the compressor was shown to be capable of very long life; a 15-ton engine/compressor assembly was shipped to Mammoth, Division of Nortec, Inc., a manufacturer of commercial-sized heating, ventilating, and refrigeration (HVAC) equipment, where independent testing will be conducted. (Sect. 4.2.1)

- Environmental chamber experiments at ORNL on a continuously capacity-modulated, electric-motor-driven heat pump were completed. The tests measured operating performance as a function of compressor speed, indoor blower speed, condenser subcooling, and type of refrigerant flow control for both heating and cooling modes. This comprehensive set of data will be used to refine analytical tools for designing higher-efficiency capacity-modulated heat pumps. (Sect. 4.2.2)

- In collaboration with the Engineering Technology Division, the design of a facility for testing cool (ice) storage systems for large commercial buildings was completed, and all major components were procured. This Ice Storage Test Facility, funded by EPRI, will allow testing of direct expansion, secondary loop, liquid overfeed, and dynamic ice maker types of cool storage systems. (Sect. 4.2.9)

B. Buildings

- A new method developed by Michigan State University for determining the thermal resistance of roof sections from in situ data was validated by simulated field measurements taken at the ORNL Roof Thermal Research Apparatus and by steady state thermal resistance measurements taken in the Metals and Ceramics Division Physical Properties Laboratory. The technique will be submitted to the American Society for Testing and Materials (ASTM) as a suggested method for field measurement of the thermal properties of insulated roofs. (Sect. 4.2.4)

- Vista Corporation, under subcontract, completed a detailed design of the Large Scale Climate Simulator (LSCS) for conducting carefully controlled experiments with low-slope roof sections, fabrication was begun, and a new building to house LSCS was constructed. This national user facility will be the heart of the ORNL Roof Research Center. (Sect. 4.1.3)

- A procedure for calculating optimum foundation insulation was developed for residential buildings and was used to show that at least some foundation insulation is cost effective in most U.S. cities despite the fact that more than 70% of new residential structures have uninsulated foundations. This procedure[5] was used to develop recommended insulation levels for the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), standard 90.2P, "Energy Efficient Design of New, Low-Rise Residential Buildings." (Sect. 4.2.3)

- Experiments at the ORNL House Test Facility in Karns, Tennessee, demonstrated that a horizontal radiant barrier (aluminum foil) laid on top of attic insulation can save significant energy for both heating and cooling loads. For these particular houses near Knoxville, Tennessee, with R-19 insulation in the attic, the cooling season savings[6] were 17% and the heating season savings about 10%. (Sect. 4.1.4)

- A cooperative study with the State of Wisconsin, the Alliance to Save Energy, HUD, the Wisconsin Energy Conservation Corporation, Wisconsin Power and Light, Wisconsin Gas, and Madison Gas and Electric showed that the cost effectiveness of low-income-housing weatherization could be improved by more than 50% using energy audits to identify the most effective conservation measures and by including HVAC as well as building envelope improvements. The average energy savings for audited houses was 170 GJ/year at an average cost (audit and retrofit) of $1600 whereas the average energy savings obtained through the Wisconsin Weatherization Assistance Program (without audit) was 80–130 GJ/year at an average cost of $2200 per home. (Sect. 4.2.5)

II. TECHNOLOGY FOR ELECTRIC POWER SYSTEMS

Electric power systems research and development (R&D) primarily involves work on the electric distribution and transmission system. The program has six major areas: (1) distribution automation and control, featuring a large-scale experiment at Athens, Tennessee, in collaboration with the Athens Utility Board and EPRI; (2) the effects of electromagnetic pulse (EMP) from high-altitude nuclear explosions on the power grid; (3) biological effects of high-voltage transmission; (4) improved dielectric systems; (5) advanced materials; and (6) high-voltage technology advances. The program includes in-house work in six ORNL research divisions and contributions by numerous subcontracted organizations. Highlights are summarized below.

- As part of the Automation and Control Experiment conducted with the Athens Utility Board in Athens, Tennessee, a high-speed data acquisition system was developed by the ORNL Instrumentation and Controls Division. Based on a minicomputer, the system can be used to monitor real and reactive power and voltage on each phase of a feeder line at rates of 10,000 readings per second. With the device, the change in real power flow was found to be sensitive to changes in voltage, and the real power increased or decreased with capacitor switching in or out, respectively, which is contrary to predictions from traditional simulation models used by the industry. (Sect. 4.2.6)

- A microcomputer-based analysis tool called the System Reconfiguration and Analysis Program was developed to simulate load transfers and capacitor switching. The program was used to simulate feeder responses to capacitor switching and load transfer on the Athens system. The simulation was generally better than could be obtained using conventional programs. (Sect. 4.2.6)

- The impact of cycling of air conditioners on feeder load was measured directly using the high-speed data acquisition system. This development is significant because it may provide a relatively inexpensive method of monitoring the effects of load control devices and strategies. (Sect. 4.2.6)

- A comprehensive program to assess the impact of EMP from high-altitude nuclear explosions on electric power systems has been established involving both experimental and theoretical methods. The program involves numerous subcontractors, including Westinghouse, LuTech, Rockwell International, Arizona Public Service, and McGraw-Edison, and is being conducted in cooperation with the Defense Nuclear Agency. Results to date indicate that (1) the large area EMP environment from high-altitude nuclear detonations can induce power line surges with over 1-MV peak voltage and a variety of pulse shapes, (2) steep-front, short-duration impulses may have a high probability of damaging insulation systems,[7] (3) corona is an important factor,[8] and (4) solid state components of communications and control systems may be damaged. (Sect. 4.2.7)

- A process developed by the ORNL Metals and Ceramics Division for producing fine-grained ZnO material for improving varistors used to control voltage surges received an IR-100 award.[9] (Sect. 4.1.4)

- Technical assistance to the National Association of Home Builders Research Foundation contributed importantly to the adoption of an addition to National Electric Code, Article 780, permitting the use of Smart-House wiring concepts (closed-loop power). This clears a major institutional hurdle from the way of developing Smart-House technologies.

III. ANALYSIS AND ASSESSMENT

This area of work, which involves studies related mainly to energy and environmental issues, policies, or technologies, is a traditional emphasis of the Energy Division. This broad theme can be divided into three parts: (1) energy and resource analysis, including evaluation of energy conservation programs, energy policy analysis with developing nations, analysis of energy use for transportation, and energy technology assessments; (2) environmental analysis and research particularly related to the preparation of environmental impact statements (EISs); and (3) emergency preparedness and response concerned with potential energy emergencies, radiological emergencies, hazardous and toxic material accidents, and even nuclear war. The following are highlights:

A. Energy and Resource Analysis

- A book entitled *Energy Efficiency in Buildings: Progress and Promise* was published by the American Council for an Energy-Efficient Economy.[10] Eric Hirst of the Energy Division was the lead author of this book, which gives a comprehensive overview of the economics, technology, and success of energy conservation in the buildings sector.

- Evaluation of the Residential Energy Conservation Action Program of General Public Utilities Corporation revealed that average net annual electricity savings in four communities in New Jersey and Pennsylvania were 1300 kWh or 6.6% of preretrofit levels. However, the results varied significantly between communities and between contractors, who are paid on the basis of measured savings. (Sect. 6.2.5)

- Using the Princeton Scorekeeping Method, the average single-family household was estimated to have saved 2900 kWh/year as a result of extensive retrofit by Pacific Power and Light of homes in Hood River, Oregon. This is considerably less than expected from preretrofit audit estimates. (Sect. 3.1.4)

- Factors influencing the performance of local agencies participating in the DOE Weatherization Assistance Program for low-income families were identified using a mailed questionnaire survey of 120 such agencies. Preliminary results indicated that agencies perform better if goals are mutually arrived at by the interaction of state and local governments, goals are frequently evaluated, reimbursement of the local agency is prompt, and some state imposed limits on expenditures are set. Performance was measured in terms of cost per energy conservation measure installed, cost per home weatherized, and number of homes weatherized in relation to annual goals. (Sect. 2.2.6)

- Evaluation of the DOE Energy-Related Inventions Program revealed that cumulative sales from program inventions were well over $200 million, which is 18 times the value of government grants supporting these inventions. (Sect. 6.1.2)

- The added cost of energy efficiency improvements to automobiles since the late 1970s was found to be approximately equal to the estimated consumer surplus resulting from these changes. This estimate accounts for both direct fuel savings and loss of performance. (Sect. 3.2.7)

- A microcomputer-spreadsheet-based Heavy Truck Technology Forecasting and Energy Demand Model was developed for use in projecting market penetration of more-efficient engines and other energy-conserving equipment on new heavy trucks. (Sect. 3.1.3)

- The ORNL MPG and Market Share Information System, the only current source of monthly fuel economy estimates for automobiles and light trucks, was improved by extension of the data base back to 1976; in addition, a system documentation and user's guide was published.[11] Also, the eighth edition of the *Transportation Energy Data Book* was published.[12] (Sect. 3.1.3)

- A general equilibrium model of the Haitian economy was constructed to assist the Haitian Ministry of Mines and Energy Resources develop the energy component of the national five-year plan. The model, which runs on a microcomputer, can be used to simulate economic impacts of fuel prices, government spending policies, tax rates, and tariffs. (Sect. 3.2.1)

- The impacts of crude oil price increases between 1971 and 1983 were estimated to have accounted for 10–90% of the debt accumulation of various African non–oil-producing developing nations. (Sect. 3.2.2)

- ORNL examined potential substitutes for wood and charcoal as household fuels in Haiti, Madagascar, and Pakistan (just beginning). In Haiti, the use of coal briquettes as a substitute was estimated to be relatively unattractive economically because of the low quality of indigenous coal deposits and because charcoal prices are very low despite growing deforestation.[13] In Madagascar, the potential use of pine plantation residues to produce charcoal was analyzed and found to be only marginally competitive in the cooking fuel market. A preference survey indicated that pine charcoal was relatively unattractive compared with commonly used charcoal from Eucalyptus (presumably because pine charcoal tends to flare and produce more fly ash). (Sects. 7.2.1 and 3.1.2)

- ORNL worked with the Costa Rican government and Hagler, Bailly & Company to design and evaluate an energy conservation program involving driver training and improved maintenance practices by taxi and bus operators. Savings of 5–10% were achieved. (Sect. 3.1.3)

- A study of the economic feasibility of recycling was published[14] in book form by Praeger Press. The principal conclusion of the book is that economic, institutional, and technological constraints significantly limit recycling outside the municipal waste stream but that recovery of chemical values (tertiary recycling) or heating values (quaternary recycling) is on the rise. (Sect. 3.2.3)

B. Environmental Issues

- For FERC, the ORNL staff devised and tested a new method for summing the effects of proposed new hydroelectric facilities on various resources (e.g., fish, wildlife, recreation, aesthetics, and the local economy). The method depends on involving concerned citizens, developers, regulators, and the scientific community in defining the importance of each resource at risk through a series of structured public meetings and technical sessions. The method was applied in the preparation of an EIS for seven proposed projects in the Owens River Valley of California; the results showed that only two projects were viable and worthy of licensing by FERC.[15] (Sect. 2.2.2)

- ORNL helped the U.S. Army prepare the draft programmatic EIS on the Chemical Stockpile Disposal Program.[16] Alternatives considered by the Army included (1) on-site disposal by incineration at each of the eight sites in the continental United States where chemical agents and weapons are stored; (2) moving the stockpile from several of the sites to two regional disposal facilities (Anniston, Alabama; and Tooele, Utah); or (3) moving the stockpile to just one site, Tooele, Utah, where all of the disposal operations would take place. As a result of significant public comment and controversy, a major effort is under way at ORNL and elsewhere to refine and expand the analysis of issues reported in the draft in preparing the final EIS. (Sect. 2.2.5)

- The psychological impacts of the restart of Three Mile Island Unit No. 1 were discussed in a new book coauthored by several ORNL staff members and published by the State University of New York Press.[17] (Sect. 2.1.6)

- In collaboration with the Air Force Geophysics Laboratory, an investigation was undertaken to identify the cause of low-frequency vibrations (subaudible) induced in buildings located near jet engine test facilities (hush houses) on Air Force bases. The origin of the vibrations appears to be a resonant mode of the hush-house structure for engine exhaust flow. This resonant mode propagates through the air and is probably caused by acoustic Cherenkov radiation. If this theory proves correct, an inexpensive solution may be possible. (Sect. 2.2.1)

- A study[18] was completed for DOE which reviews the issues associated with increased use of chlorofluorocarbons and the effects of releases of these compounds on the stratospheric ozone concentration and on global atmospheric warming (the greenhouse effect). A very wide range of scenarios involving various emission rates and the rate of introduction of substitutes was investigated; although the conclusion suggested that time for further investigation of issues is available (one or two decades), it seems prudent in the near term to identify and develop needed alternatives especially for essential uses such as fluids for heat pumps and refrigeration equipment. (Sect. 7.2.4.)

C. Emergency Preparedness/Response

- A regional analysis tool called the Integrated Management and Economic Analysis System was developed for FEMA to provide a modeling and data analysis tool for estimating the regional/national economic impact of disasters anywhere in the country. The system uses a microcomputer front end to interface with the FEMA central mainframe and associated data bases. (Sect. 3.1.2)

- Studies for the U.S. Army Corps of Engineers resulted in models to estimate the economic damages and loss of life from dam-related flood events, a protocol to assess the effectiveness of warning and evacuation plans, and a traffic simulation model to estimate the size of the threatened population by comparing network clearance times with flood travel times. (Sect. 3.1.4)

- Two analyses were completed for the Office of Energy Emergencies of DOE concerning emergency response to damage of critical components: one for oil and gas distribution facilities and the other for electricity generating and transmission equipment. The results of the former indicated that, for most damage scenarios, jury-rigging could restore at least partial operating capability in a short time; some scenarios could cause severe, long-term disruptions. In the second study, Southern Electric International, under subcontract, found that the electric utility industry has no planning or component stocking practices to recover from coordinated sabotage of bulk power facilities and that some critical components not stocked have lead times of months. (Sect. 2.1.7.2)

- A series of state-of-the-art papers was completed for FEMA on topics including postdisaster economic recovery; shelter for surviving nuclear war, including the implications of nuclear winter; evacuation; warning; emergency food and water; and land contamination. (Sect. 2.1.7.3)

- The Navy Mobility Fuels Forecasting Systems[19,20] was used during FY 1986 to estimate the effects of various disruptions on the availability of military jet fuel (JP-5) and marine diesel fuel (F-76). The analysis suggested that supplies could be insufficient during a major Persian Gulf crude oil supply disruption. (Sect. 7.2.3)

- A study of the oil situation suggests that (1) disruptions in future supply are not unlikely; (2) some recent changes in the structure of the market, such as vertical integration by the Organization of Petroleum Exporting Countries members, may damp adjustments to shortages, thus causing severe impacts; and (3) linear programming models, such as the EIA Petroleum Allocation Model, should be very useful tools for assessing the degree of impact given the constraints on transportation, trade, and refining possibilities. (Sect. 3.1.1)

IV. DATA SYSTEMS RESEARCH AND DEVELOPMENT

Data systems R&D involves work to develop tools, methods, models, and systems that will be useful in collecting, organizing, evaluating, and analyzing large amounts of data to improve decision making, operational efficiency, and data and model availability in large public organizations. This activity derives from past efforts involving the use of large data bases to analyze various energy and environment issues such as power plant siting, regional economics, and energy demand forecasting.

The research includes work on decision support methodologies, such as expert systems; efforts to develop systems that are more nearly machine-type independent; work on networking and integration in a distributed processing and user environment; and design and prototyping of new systems, including those using advanced data management approaches. Hence, the work is a combination of methodological development and state-of-the-art applications to data system problems.

A. Applications

- ORNL completed a decision paper for EPA on the Resource Conservation and Recovery Act (RCRA) Information System, which is intended to provide record keeping and data processing for the national hazardous waste program authorized under RCRA. ORNL recommended the development of a distributed system including a two-domain design of data bases, one used for program implementation and the other for program oversight. This permits the states to assume responsibility for maintaining up-to-date data for their RCRA projects separate from the data EPA needs for oversight, management, and evaluation. (Sect. 6.2.6)

- Also for EPA, ORNL developed a computer based workstation to assist the EPA Hazardous Waste Ground Water Task Force with its mission to evaluate the groundwater situation at 57 commercial hazardous waste sites around the country. The tool features map digitization;

overlay construction; graphics for displaying chemical, geologic, and hydrologic profiles; statistical packages; and a variety of groundwater pollutant transport models. (Sect. 6.2.2)

- Under the Navy Regional Data Automation Center sponsorship, an optimizing algorithm to convert information about cargo ships, ports, and times into detailed ship routes and cargo schedules was developed for the Military Sealift Command. The solution procedure included two parts: first, resource allocation using linear programming to determine ship routing; and second, detailed scheduling to assign specific cargos to the previously routed ships. A prototype of this algorithm (called SAIL) was delivered to the Navy for testing in September 1986. (Sect. 6.2.1)

- Advanced software engineering techniques [Problem Statement Language/Problem Statement Analyzer (PSL/PSA)], coupled with a state-of-the-art relational data base management system supplied by ORACLE Corporation, are being used to create better tools for operating the DOD personal property transportation system. Successful early prototyping of two of the five modules of the tool, which is called TOPS (Transportation Operational Personal Property Standards System), demonstrated the usefulness of the software engineering techniques for developing large, complicated software systems requiring intensive interactions between the ORNL developers and the users, who are personnel from all four branches of the armed forces. (Sect. 2.2.3)

- The computer-aided instruction program developed by ORNL for the Navy shipboard nontactical automated data processing system was improved to facilitate quick errorless lesson modifications, encryption for security questions, generation of various reports for students and instructors, and development of a new computer loading method that reduces loading time on the Honeywell SNAP I computer from 3 to 4 h to less than 30 min.[21] (Sect. 6.2.3)

B. Methods

- A large-scale experiment was performed on the Oak Ridge computer network demonstrating that widely dispersed (up to 20 miles) Ethernet Local Area Networks (LANs) could be bridged to the area broadband cable so that the whole system operated as one logical Ethernet LAN demonstrating transmission rates in excess of 1 MB/s. The bridges were supplied by Applitek Corporation and supported several high-level network protocols simultaneously, including DECnet, XNS, and TCP/IP. As a result of the experiments, several improvements to the N110/E bridge were made by Applitek. (Sect. 5.2.2)

- A methodology developed by Sage Federal Systems, Inc., was evaluated for automatically translating machine-dependent COBOL to machine-independent source code, and 65,000 lines of COBOL-68 were successfully converted to COBOL-74 source code. (Sect. 5.1.4)

- Several expert systems are under development for several sponsors, including two for the Navy, one to assist detailers with matching jobs to people and the other to organize and analyze budget request data. In addition, a project is under way to help BPA identify how, or if, expert systems can be useful in power system planning and the operation of the transmission grid. Also, a survey was completed for the Air Force reviewing the state of expert systems applications to command and control. (Sect. 6.2.4)

- Research .. automated knowledge acquisition focused on self-administered surveys of an individual's uncertainty perceptions. The objective was to determine how people reason about uncertainty as it relates to commonly encountered risks and other events. Approaches (rules) that people use to reason about risk are found to be context dependent. (Sect. 6.2.4)
- Research on machine learning focused on the use of genetic algorithms and classifier systems to solve job shop scheduling and simulated robot navigation problems. Both activities have shown promising results. For example, the scheduling system has been able to "discover" correct rules. (Sect. 6.2.4)
- Experiments conducted with the Instrumentation and Controls Division showed that the Novix chip, a microprocessor using Froth as it machine language, could process rules in the "Towers of Hanoi" problem at a rate equivalent to about 5000 rules per second. This result indicates that very rapid expert system rule processing may be possible on microcomputers when the processor architecture is optimized to the specific task. (Sect. 6.2.3)

1.3 RESEARCH UTILIZATION

The staff of the Energy Division has an obligation not only to do high-quality work and advance the state of understanding in our various research areas but also to promote the dissemination of the research results and to encourage use by the private sector of developments that may have commercial applications. Of course, the primary users are the sponsors of the work, but broader technology transfer and information dissemination are generally encouraged. This is accomplished in a wide variety of ways, the most significant of which are mentioned here and at the end of each of Chaps. 2–7 that describe the work of the Division's sections.

Our success at research utilization is vital. The national laboratories can contribute more importantly to the productivity and welfare of the country if we are successful; and to be so, we must find new ways of creating partnerships with the private sector and of designing technologies that can meet the conditions of public acceptance. To these ends, we are developing the concept of a Center for Technology Utilization that will conduct research on both technology transfer and technology acceptance.

For years, we have been working closely with private sector firms to conduct R&D leading to proof of concept of advanced energy conservation technologies. In these efforts, the innovation process is initiated by companies that can carry successful concepts to commercialization. This approach is now being applied to absorption heat pumps with Phillips Engineering, Carrier, and Trane; the Braun engine heat pump with Tectonics Research, Inc., Minnesota Gas Company (Minnegasco), Northern Natural Gas Company, and Mammoth Division of Nortec, Inc.; and the Stirling Engine heat pump with Mechanical Technology, Inc., GRI, and Lennox Corporation.

ORNL is also serving as the lead laboratory for technology transfer for the Office of Buildings and Community Systems (OBCS) of DOE. Activities include organizing two annual training institutes, one for engineering faculties and one for architectural faculties; documenting and analyzing successful commercialization effort of OBCS-supported R&D; evaluating other technology transfer activities; developing a strategy for encouraging the trade press to report on OBCS R&D results; developing tools to allow architects, engineers, and consumers to more easily evaluate energy-efficient design, equipment, and products; and completing a technology transfer plan for OBCS.[22]

For a number of program areas, we have established advisory committees consisting of representatives of manufacturing firms and utilities. These include a committee formed by the Air Conditioning and Refrigeration Institute to oversee work on building equipment, particularly heat pumps; a utility advisory committee for the Athens Distribution Automation Experiment; and groups to advise our work on EMP, building foundations insulation, and the Roof Research Center. The latter is particularly noteworthy, as it consists of people from the roofing industry and major roof owners such as the Navy. This committee has helped ORNL specify and design the large environmental chamber that will be the heart of the center. It has also helped us to organize research priorities. This input is essential because the Roof Research Center has been designated a national users facility, and a DOE objective is to encourage users to contribute a substantial part of the operating costs of the Center. All of these advisory groups have been most useful in helping us decide what research is most important to do, critiquing results from our work, and helping disseminate relevant results to the potential users.

Four staff members were on assignment during the year. Phil Fairchild spent a year at EPRI working with the EPRI staff on heat pump programs. This improved the interaction between the DOE and EPRI programs and has lead to joint planning. Horacio Perez-Blanco worked for a year with Ben Phillips of Phillips Engineering on advanced absorption heat pumps. This assignment has sped the development process and also provided a useful and practical learning experience for Dr. Perez-Blanco. Steinar Dale began a one-year assignment as an IEEE Congressional Fellow detailed to the House Committee on Science and Space and Technology to work on a study of technology policy. Finally, Eric Hirst began a one-year work assignment at Puget Sound Power and Light to help develop an analytical and organizational process to make decisions about power systems planning in which options for capacity expansion and programs that reduce demand are compared on a consistent basis involving consideration of cost, risk, and other factors.

The staff are active on numerous professional society committees. During FY 1986, our work influenced three industry consensus standards. One is an ASTM Standard on field measurements of thermal performance of insulated roofs; the second is a standard by ASHRAE on estimating optimal thermal insulation for foundations; and the third is the National Electric Code addition on the Smart-House wiring.

A growing number of utilities are using the results of evaluation studies of conservation programs carried out over the past several years. Utilities include BPA, Pacific Power & Light, Puget Sound Power and Light, General Public Utilities, Florida Power and Light, Northeast Utilities, Northern States Power, Minnegasco, Union Heat and Light, and Louisville Gas and Electric. These studies have led to the development of numerous methods of evaluation useful in a wide variety of utility situations.

Occasionally, methods developed for one sponsor are useful to other federal or state agencies or even to developing nations. For example, research done for NRC and DOE resulted in the development of a method for estimating in real time the dispersion of plumes carrying pollutants emitted into the atmosphere during accidents. A system employing this method has been set up and successfully tested at DOE facilities in Oak Ridge. The southeastern region of EPA is adopting the plume model from this method for application by communities requesting assistance in emergency preparedness and response (see Sect. 2.3 for more details). Additionally, the groundwater work station developed for the Ground Water Task Force of EPA will be adapted for use by EPA regional offices and perhaps by the state of California as well (see Sect. 6.3.3 for further discussion). The ORNL National Highway Network, the most accurate and detailed in existence, was produced for the U.S. Army starting with a network developed by the U.S. Geological Survey.

The ORNL version, greatly enhanced, has now been transferred to the Department of Transportation. Our program for AID is leading to the transfer of various technologies and methods to developing nations, including energy/economy models, knowledge of electric transmission and distribution systems, a model for evaluating woody biomass plantations, and ideas for transportation energy conservation.

Various models developed by Energy Division staff are requested by a wide variety of users. For example, transportation energy demand, automobile market simulation, and consumer's surplus models and calculations have been transferred to various researchers in the United States and abroad, including General Motors Research Laboratory. The High Occupancy Vehicle Simulator Model was distributed in beta test to two California planning groups, and the ORNL Heat Pump Simulation Model continues to be requested by industrial firms and various research organizations.

Work for the Navy on LANs and bridges between LAN and broadband networks is proving useful to ORNL and Energy Systems for improving computer networking. Energy Division staff have provided advice about LANs to DOE-ORO and to the Environmental Sciences Division at ORNL. This work on testing bridges has led to product changes by the developer, Applitek. Also, work on a test version of the Novix chip microprocessor has led to suggested changes in chip architecture to the manufacturer.

Finally, technical communications and information dissemination included interaction with peers, sponsors, and the interested public and the recording of results of work as part of the technical literature (see Chap. 8). During FY 1986, the staff published 43 articles in scientific or technical journals, and 27 others were accepted for publication. In addition, 95 ORNL and sponsor reports, 1 book, and 12 book chapters were published; 42 papers were printed in proceedings of technical meetings; and 21 environmental impact statements, assessments or appraisals were issued in draft or final form. Additionally, the Division held or organized 10 workshops and symposia and hosted many visitors from universities, government organizations, industry, and other research institutions.

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2. Integrated Analysis and Assessment Section

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2.1 INTRODUCTION

Because of the matrix mode of operation of the Integrated Analysis and Assessment Section (IAAS), the work reported is, to a considerable extent, the result of supporting expertise from other ORNL divisions, including Environmental Sciences, Health and Safety Research, and Environmental and Occupational Safety, and the Information Resources Organization. The work also reflects the support given by a number of subcontractors, including The University of Tennessee, Colorado State University, Tulane University, and the Mitre Corporation.

As has been the case for the last several years, the U.S. Department of Energy (DOE) and the U.S. Department of Defense (DOD) were our major sponsors during the past year in both the National Environmental Policy Act (NEPA) and applied research areas. The U.S. Nuclear Regulatory Commission (NRC) and the Federal Emergency Management Agency (FEMA) also contributed large fractions of our workload.

We do not ordinarily accept the more routine tasks from our sponsors, although, admittedly, some of our work does fit into this category. Our philosophy is to accept only those tasks that are difficult, unique, and challenging to our staff. While such a policy carries with it an enhanced risk for failure, it is consistent with the general philosophy that research in high-risk projects should be conducted at the national laboratories. Following are typical projects that fall into the nonroutine category and demonstrate the breadth and range of problems on which the section is currently working.

Sponsor	Task	Progress
DOD	Chemical Stockpile Disposal Program NEPA Review	Issued Draft Programmatic Environmental Impact Statement (EIS) (Sect. 2.2.5)

*In October 1986, J. B. Cannon was named to head the Integrated Analysis and Assessment Section.

DOD	Transportation Operational Personal Property Standard System (TOPS)	Prototype stage completed (Sect. 2.2.3)
DOD	Vibroacoustic impacts of hush-house operations	Problem and cause identified (Sect. 2.2.1)
DOE	Field Material Production Center (FMPC) Fernald EIS	Specific areas of concern identified
DOE [Federal Energy Regulatory Commission (FERC)]	Owens River Basin EIS	Draft EIS issued (Sect. 2.2.2)
DOE	Analyses for Developing a Low-Level Waste Disposal Facility on the Oak Ridge Reservation	Site selection study completed, and preliminary pathway analysis carried out (Sect. 2.2.7)
FEMA	State-of-the-art assessments—national preparedness	See Table 2.2 for various projects (Sect. 2.1.7)
NRC	Development of a fluid-flow model for predicting excursions at in situ uranium mining sites	Paper in draft

2.1.1 NRC and FERC Programs

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2.1.1.1 NRC projects

The NRC Program continues to support the needs of the NRC in the areas of (1) licensing of the operating phase of nuclear power plants, (2) renewal of licensing of nuclear fuel cycle facilities, and (3) aiding NRC in implementing established NRC licensing and regulatory policies regarding

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uranium recovery facilities. With the publication of the final environmental statement for South Texas,[1] our four-year involvement in the licensing of operating nuclear power plants was completed. Eleven documents in this series have been published over the last four years. Renewal of licenses for nuclear fuel cycle facilities has resulted in the preparation of environmental impact appraisals for Nuclear Fuel Services and Mallincrodt facilities. These reports are undergoing NRC review and will be published in FY 1987.

Uranium recovery facility work has heavily involved us in both field data collection and theoretical development in relation to groundwater contamination problems at uranium mills and mines. These activities included the following:

1. production of an IBM-PC-compatible version (with a mainframe interface) of the MIGRAT[2] code for groundwater flow and contaminant transport,
2. development of a testing procedure for determining riprap durability,
3. development of a fluid-flow model for predicting excursions at in situ uranium mining which significantly increases the state of the art of classical theory, and
4. determination (at Colorado State University) of the stability of uranium mill tailing impoundments through the use of flumes.

These studies were completed in FY 1986 and are currently in review. The results will help provide a basis for NRC to establish policy for the management and licensing of uranium milling and mining activity. In addition, ORNL is preparing a Regulatory Guide and Standard Review Plan to provide guidance to facility operations submitting acceptable environmental reports and to NRC staff in assessing input from applicants. We believe these studies are timely in light of the pressing needs of nuclear waste management.

2.1.1.2 FERC projects

Our work with the Office of Hydropower Licensing has steadily grown since 1982 when the environmental impact assessment of the Susitna Hydroelectric Project in Alaska was initiated. This assessment produced recommendations that, in part, resulted in the applicant submitting a revised license application. Because of changing power projections in Alaska, the applicant has withdrawn the project from further consideration by FERC.

A methodology for evaluating environmental impacts of multiple projects was developed for the Upper San Joaquin River Basin, California.[3] The methodology has served as a basis for the Cluster Impact Assessment Procedure that FERC is using for evaluation of the effects of multiple projects within river basins across the nation. This year, we further refined the methodology and applied it to the evaluation of seven hydroelectric projects in the Owens Valley, California (see Sect. 2.2.2).[4] The procedure uses a matrix approach to quantify the cumulative effects of development on resources of concern (e.g., fish, wildlife, recreation, aesthetics, and local economy) and to demonstrate the need for, and resulting effects of, mitigation on these resources.

2.1.2 DOE Nuclear Program

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The DOE Nuclear Program continues to focus on Oak Ridge Operations (ORO) facilities, principally those operated by Energy Systems. The breadth of activities undertaken this year ranged from the preparation of Action Description Memorandums (ADMs), which are scoping documents to determine the required level of NEPA documentation, to management and execution of environmental assessment and related tasks for cleanup of past waste problems at the ORNL complex and for developing a new low-level-waste (LLW) disposal facility.

ADMs were prepared for (1) closeout of the Atomic Vapor Laser Isotope Separation activities at the Oak Ridge Gaseous Diffusion Plant and (2) closeout of the Gas Centrifuge Enrichment Program. These ADMs were needed in conjunction with DOE's decision on the need for uranium enrichment capacity and related research and development activities. An ADM was also prepared for the sale of Segment O of the Oak Ridge Reservation to the City of Oak Ridge. The City plans to sell the land to Boeing Tennessee, Inc., for use in the storage, final assembly, and electrical (functional) testing of DOD missiles.

The Program is also providing support to DOE/ORO in the area of NEPA Compliance for the FMPC, which is a DOE facility located near Fernald, Ohio (about 20 miles northwest of Cincinnati). At the FMPC, currently operated by Westinghouse Materials Company of Ohio, Inc., a wide variety of chemical and metallurgical process steps are used to convert uranium hexafluoride and recycle materials to machined uranium ingots for fabrication of uranium billets and target element cores used in U.S. defense programs. DOE has proposed to renovate the FMPC and to conduct remedial actions at sites of contamination from historical waste disposal practices. Principal tasks in the area of NEPA support at FMPC are the development of a comprehensive strategy for conducting the renovation and waste cleanup activities in accordance with NEPA and associated regulations, preparing an EIS addressing these activities at FMPC, and preparing NEPA documents for specific renovation and/or remedial action projects. FMPC NEPA support is expected to run through FY 1989.

The Program continued its lead role in site characterization and performance modeling tasks of the Low-Level Waste Disposal Development and Demonstration Program. This program is focused on the development of a new LLW disposal facility on the Oak Ridge Reservation during the next several years. Notable tasks undertaken and completed this year include (1) a survey of LLW acceptance criteria for disposal facilities in the United States and abroad, (2) a review of the NRC

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classification system (10 CFR 61) for LLW to develop such a system for ORO facilities, (3) a site screening study based on recently developed criteria to find a suitable LLW disposal site on the Oak Ridge Reservation (Sect. 2.2.7), and (4) a pathways analysis study to ascertain the LLW disposal capacity for various potential Oak Ridge Reservation sites.

The Program's involvement in the cleanup of past waste problems at ORNL (i.e., the ORNL Remedial Action Program) was aimed at developing background information and methodologies for environmental assessments and related tasks. The Remedial Action Program is concerned with more than 100 inactive sites, ranging in complexity from abandoned waste storage ponds and tanks to large experimental reactors and waste disposal sites. An overall comprehensive NEPA strategy has been developed for corrective action at the sites, and reconnaissance data were compiled for each site. These data included site location and description, history, contaminants and their characteristics, extent of contamination, regulatory status, geology, hydrology, and ecology. Because these types of data will ultimately be used to select a remedial action for a specific site, a method[5] was developed to evaluate the effectiveness of alternative remedial actions in reducing the environmental impact of a given waste site and to rank the alternatives. The Analytical Hierarchy Process developed by T. L. Saaty was modified for these purposes. A hierarchy model was developed, criteria in the general areas of risk and benefit were formulated, and weights were assigned to the criteria. The model was then tested using available characterization data with regard to two general remedial action alternatives (excavation and containment) applied to four case study sites at ORNL. The resultant numerical ranking for an alternative given by the model was interpreted as the benefit of a given remedial action at a given site. By using preliminary cost estimates developed for each of the alternatives at the case study sites, benefit-cost ratios were computed. Results indicate that containment has a higher benefit-cost ratio than excavation (assuming an 80-year time frame under alternative discount rates of 5% and 10%). Based on the test cases studied, the model was judged to be useful in meeting the desired goals, although modification of some of the criteria was recommended.

2.1.3 Nonnuclear and Air Force Programs

C. R. Boston*

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D. B. Hunsaker, Jr.	D. W. Lee	R. D. Roop	

The Nonnuclear and Air Force Programs of IAAS can be divided into four categories: Air Force, fossil, geothermal, and alcohol fuel projects. The Air Force support work is a major activity initiated by the IAAS during FY 1985 to provide environmental technical support to the Air Force.

The initial sponsor of the Air Force support projects was the Air Force Engineering and Services Center located at Tyndall Air Force Base, Florida. During FY 1986, sponsorship was

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broadened by means of new interagency agreements with most major commands (e.g., Air Force Reserve, Air Force Logistics Command, Strategic Air Command, Tactical Air Command, and Space Command). With this breadth of coverage, it is not surprising that this rapidly expanding activity has provided a unique challenge to IAAS staff in coping with a wide range of environmental problems and settings.

Air Force projects involved

1. conducting site screening studies using ORNL's unique computer graphics capabilities whereby sites and alternative sites for a proposed Southeast Bombing Range were identified;
2. initiating a generic EIS and conducting assessments for low-level flight training routes (see Sect. 2.2.4);
3. conducting socioeconomic studies relating to third-party financing, personnel transfers, off-base impacts, and cultural and aesthetic impacts (see Sect. 2.2.4);
4. conducting detailed noise analyses for proposed mission changes;
5. conducting studies of noise-dampening facilities (hush houses) (see Sect. 2.2.1); and
6. conducting impact analyses for packaging, transporting, and disposing of depleted uranium waste from munitions testing.

In the fossil area, the IAAS continued to manage the Fossil Energy Technology Environmental Program (FETEP). This program encompasses a wide range of activities in support of DOE's Office of Oil, Gas, Shale, and Special Technologies. These activities include technical reviews of environmental monitoring plans for synthetic fuel (synfuel) projects. This work assists DOE in discharging its responsibility mandated under Sect. 131(e) of the Energy Security Act as a consulting agency (along with EPA) to the Department of the Treasury in reviewing environmental monitoring programs and data resulting from those programs conducted by sponsors of synthetic fuel projects who obtained financial assistance from the former Synthetic Fuels Corporation (SFC). The reviews evaluate the adequacy of, and compliance with, each plan. During FY 1986, environmental monitoring plans for each of the four projects funded by SFC were completed and approved. The projects included the Cool Water Coal Gasification Program, the Dow Syngas Project, the Forest Hill Heavy Oil Project, and the Parachute Creek Shale Oil Program Phase I Project. ORNL provided environmental health and safety reviews of 12 documents during FY 1986. Another FETEP activity performed in conjunction with ORNL's Information Resources Organization is the management and analysis of information related to the SFC's environmental monitoring requirements. During FY 1986, selected monitoring data generated by synfuels plant sponsors were analyzed and selectively entered in the FETEP Information System data base for on-line retrieval by the program sponsor and DOE's Energy Technology Centers (ETCs). Additional analyses were conducted in support of DOE's Office of Advanced Fuels, Technology, Extraction, and Environmental Controls as a participant in the SFC's Monitoring Review Committee activities related to synfuels projects.

Support to DOE/Fossil Energy (FE) continued in the Environmental, Safety and Health project, with assistance from ORNL's Health Division. The project entered its eighth year of providing technical support to FE in managing environmental protection, occupational safety, and health protection programs at FE facilities. In the past, support was provided to the ETCs in the areas of industrial hygiene quality assurance, emergency planning, hazard analysis, industrial ventilation, and safety and health training for employees and supervisors. One of the new initiatives in FY 1986 was the support of the Pittsburgh ETC to develop a materials safety data base.

Work for DOE/ORO's Strategic Petroleum Reserve (SPR) Office was completed in FY 1986. Deliverables included a final environmental assessment[6] (EA) and associated environmental documents (e.g., Floodplains/Wetlands Assessments and Statements of Findings) for alternative crude oil distribution enhancements at the SPR Seaway Complex (Freeport, Texas).

In the area of geothermal projects, we continued to provide support to the DOE/San Francisco Operations Office on loan guaranty projects and to DOE/Headquarters on geopressure projects. An environmental analysis was conducted for the Pleasant Bayou Geopressure Well Utilization (Hybrid) Project in Texas.

2.1.4 Technology and Social Systems Group

R. B. Braid*

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C. E. Easterly[†]	B. D. Lasley	S. F. Rayner	J. Van Dyke
L. P. Gerlach[§]	F. Latham[‡]	R. M. Reed[¶]	A. K. Wolfe

2.1.4.1 Research focus

The Technology and Social Systems (TASS) Group emphasizes research directed at understanding the institutional mechanisms by which society manages technologies. From the technology standpoint, it is critical that the full range of potential impacts to society be understood so that appropriate institutional responses can be implemented to guide development of the technology. From society's standpoint, it is vital that those institutions reflect a high level of public trust, operate according to procedures to which society has given its consent, and provide for an equitable distribution of cost and risk liabilities in implementing the technology. To further these research objectives, the TASS Group carried out projects in the topical areas of social impact assessment and institutional organizational analyses.

2.1.4.2 Social impact assessment

Social impact assessment again proved to be the focus of most of the TASS Group's projects during FY 1986. The major effort involved leadership of and heavy participation in four large EAs[7-10] for Air Force low-altitude training operations conducted by either the Strategic Air

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Command (SAC) or the Tactical Air Command. These assessments examined the potential impacts to humans, animals, and structures of flying B-52, B-1B, and F-15 aircraft at altitudes as low as 300 ft above ground level. ORNL has played a major role in assisting SAC in developing greatly improved methods for conducting its EAs. As a result of this work, ORNL has begun, at the Air Force's request, a major two-year effort to develop a generic environmental impact statement (GEIS) for the Air Force's entire low-altitude flying operations. These training operations are conducted on over 700 low-level routes and in other areas that traverse many thousands of square miles of land. The GEIS will emphasize the assessment of actual impacts of a representative sample of such operations and the development of referable scientific documentation for key types of impacts.

Members of the TASS Group were also involved in a variety of other assessments led by other groups within the section, including one that examined the possible siting of a large low-frequency communications facility with numerous antenna which created significant public acceptance problems. Another project involved examining the socioeconomic impacts of constructing and operating an electromagnetic pulse test facility. Another assessment concerned possible socioeconomic impacts of restoring contaminated production facilities at the Fernald plant. Other assessments examined the potential impacts to property values caused by new flying operations at Westover Air Force Base and the community impacts associated with the destruction or removal of obsolete Army chemical munitions at eight sites (see Sect. 2.2.5).

2.1.4.3 Institutional and organizational analysis

The TASS Group continued to explore various aspects of how organizations manage or regulate technologies. The major effort was the evaluation of DOE's Weatherization Assistance Program in which the group examined why some local-community-based groups do an effective job of weatherizing low-income homes while others do not (see Sect. 2.2.6). TASS Group personnel also participated in a project for FEMA. This research was a comperative evaluation of how market exchanges and property rights are likely to be maintained under alternative institutional arrangements arising after major societal disasters, such as nuclear war. Group staff also assisted the DOE Office of Energy Emergencies in the evaluation of the SPR Test Drawdown.

The public acceptance research under way for the Air Force (Sect. 2.2.4) explores the Air Force's institutional relationship with the public. Issues such as the amount of information the Air Force provides the public, the discontinuity between Air Force training operations and human populations in the area, and the response of the Air Force to complaints from the public are all being considered in various phases of the work. Objectives of this effort are to understand the impacts to the human population and how Air Force organizational behavior shapes those impacts. From this research it is hoped that appropriate mitigative measures can be developed that will reduce human impacts and improve Air Force capabilities in managing its training activities to be consistent with the needs of the public.

2.1.5 Applied Physical Sciences Group

A. J. Witten*

J. M. Bownds	J. P. Loftis	M. M. Stevens
S. W. Diegel	R. D. Sharp†	S. S. Stevens
R. O. Johnson	P. T. Singley	J. G. Tuggle†
D. W. Lee	P. M. Spears	T. G. Yow

The Applied Physical Sciences Group contains the IAAS's experts on fluid dynamics, geohydrology, geophysics, applied mathematics, and software engineering. Members of this group provide technical support for many of the section's interdisciplinary projects and perform independent research in their areas of expertise.

The largest ongoing project is the TOPS project supported by DOD. For this project, ORNL is providing the expertise to complete the functional description of, and the technical specifications for, a fully integrated information management system to track the movement of the personal property of members of the U.S. Armed Services. Following completion of these tasks, we will assist the Military Traffic Management Command in the installation and implementation of the resulting system. Six group members are devoted full-time to this project. For more details on the TOPS project, see Sect. 2.2.3.

The group has continued its research in diffraction tomography. Support for geophysical applications was far below that of previous years; however, within the funding constraints, the data acquisition system was modified to provide greater efficiency in data collection. Our experience in geophysical diffraction tomography has led us into a new research area—medical ultrasound tomography. This research could prove to be quite important because ultrasonic imaging promises to provide a relatively inexpensive diagnostic tool for noninvasive soft-tissue characterization. In collaboration with the University of Rochester's Medical Ultrasound Laboratory, we are attempting to image a tissue-mimicking "phantom" composed of gelatin and agar. If this work is successful, it could lead to the development of an imaging device having no moving parts and capable of providing high-resolution imaging of basic tissue characteristics including density, compressibility, and attenuation.

During the past year, the group has undertaken two projects for the Air Force involving vibroacoustics. One involves an assessment of impacts associated with low-frequency acoustic emissions produced by hush houses, hangar-like structures in which aircraft engines undergo diagnostic tests. During engine operations, these buildings have produced subaudible pressure waves that have induced significant vibrations in nearby buildings. ORNL is investigating these known impacts as well as other suspected impacts. A discussion of the building vibration problem and a promising mitigation strategy are given in Sect. 2.2.1. The second vibroacoustic project involves an assessment of the potential short- and long-term damage that could occur to ancient Indian cliff dwellings in the Southwest as a result of vibrations produced by low-flying bombers. This project is being performed in collaboration with the Air Force Geophysics Laboratory and with the cooperation of the Navajo Nation.

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*Group Leader.

†On Loan from Computing and Telecommunications Division.

A significant portion of the resources of the group is devoted to hydrologic and geohydrologic support for DOE/ORO activities. These projects address the impacts of waste disposal on the ORNL reservation and other sites operated for DOE/ORO (see Sect. 2.2.7).

2.1.6 Hazard Management Group

S. A. Carnes*

D. M. Neal J. H. Sorensen

The projects involving members of the Hazard Management Group in FY 1986 revolved around the management of technological and/or natural hazards and required the input of multiple disciplines. Although the major project in the group continued to be the preparation of NEPA documentation for disposal of chemical munitions (see Sect. 2.2.5), other major efforts included work for (1) FEMA on evacuation and warning systems, (2) the Office of Energy Emergencies of DOE on recovery of oil or gas distribution facilities following sabotage (also see Sect. 2.1.7.2), and (3) the Army Corps of Engineers on warning and evacuation capabilities near Corps' hydroelectric facilities (also see Sect. 3.1.4).

A new state-of-the-art assessment on emergency warning systems was initiated. This research deals with the study of warning systems to determine both the adequacy of, and the possible improvements to, such systems currently used to alert the public to a range of natural and technological hazards, including floods, earthquakes, tsunamis, hurricanes, tornadoes, volcanic eruptions, landslides, dam failures, nuclear power accidents, hazardous material releases, and nuclear crises. The research summarizes existing information on organizational warning processes, individual response to warnings, and warning practices. Conclusions will be oriented toward improving the design and implementation of emergency warning systems for a variety of hazards.

The evacuation research led to the publication of a report[11] detailing the nation's experience with evacuations caused by releases of hazardous materials. Approximately 300 events that caused people to evacuate occurred in a five-year period. For every 1,000 people evacuated, 8 exposure injuries were reported. The average evacuation involved the movement of 1,000 people, with the largest impacting 30,000.

In addition, a draft of an annotated bibliography summarizing research findings on evacuation and a draft final report identifying and analyzing evacuation planning issues were prepared. The bibliography lists over 250 works on evacuation and summarizes many of them. The report synthesizes this information to address policy and planning issues.

The final major effort with which our group was associated involved an evaluation of existing warning and evacuation systems near Army Corps of Engineers' hydroelectric facilities. The systems in place at two dam sites were evaluated by studying disaster plans of local emergency organizations, including the Corps', and talking to Corps and local emergency management officials. It was found that the Corps is capable of detecting dam problems that could initiate a warning and evacuation. Once this information is relayed to local officials, however, the quality of planning for emergency response decreased significantly.

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*Group Leader.

As a result of work carried out in previous years for the NRC, a publication covering the controversy and possible impact of restarting the Three Mile Island-1 (TMI-1) reactor was completed.[12] While the research has its genesis in the controversy surrounding the NRC decision to allow the restart of TMI-1, it has much broader implications. The book addresses the implications for psychosocial impact measurements, environmental policy, impact mitigation, and hazard management in a much broader sense than merely in relation to the restart of TMI-1. Hazardous technology management and the public acceptance thereof have become major issues. This book attempts to identify important parameters for public acceptance and to demonstrate how the lessons of TMI could be extended to other hazardous technologies. It shows that the complex decision-making about technology is composed of many technical, social, scientific, economic, psychological, and political factors. This highly important book does much to establish ORNL as a center of expertise in the area of public acceptance of hazardous technologies.

2.1.7 Emergency Technology Group

C. V. Chester*

M. V. Adler K. S. Gant G. P. Zimmerman

2.1.7.1 Office of Nuclear Safety

The Emergency Technology Program continued to provide assistance to DOE's Office of Nuclear Safety in the area of radiological emergency preparedness. ORNL staff members played major roles in the planning, conduct, and evaluation of the Relocation Tabletop Exercise (December 1985), an interagency exercise that looked at the postemergency response to a radiation accident. Planning was begun for the second Federal Field Exercise, a large interagency exercise to be held in June 1987 at the Zion power station, as well as for other exercises. ORNL wrote and helped produce a videotape, "Federal Radiological Emergency Assistance," for DOE use.

Under this program, a topical meeting (jointly sponsored by the American Nuclear Society and NRC), "Radiological Accidents—Perspectives and Emergency Planning," was held in Bethesda, Maryland, in September 1986. Other organizations participating were FEMA, the Environmental Protection Agency (EPA), the U.S. Department of Transportation, the National Emergency Management Association, the Conference of Radiation Control Program Directors, and the Health Physics Society. The meeting was highly successful. Sixty-eight papers were presented or exhibited, and total meeting attendance approached 300.

Work was begun on a design concept for a machine to remove the surface layer of unpaved, highly beta-gamma-contaminated land. The machine concept is based on a large commercial vacuum truck with custom equipment to control surface removal and remote control of vehicle position and travel.

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*Group Leader.

2.1.7.2 Office of Energy Emergency Operations

A study of critical replacement components of electrical transmission and generating equipment systems was completed. The study, which was undertaken for the Office of Energy Emergency Operations of DOE by subcontract with Southern Electric International of Atlanta, found that the industry has no planning or component stocking practices to recover from coordinated sabotage of bulk power facilities. Some critical components are available or can be jury-rigged, but others are not stocked and have lead times of months.

Research on restoration of services following sabotage of an oil or gas distribution facility was completed for DOE's Office of Energy Emergencies. The work concluded that many damage scenarios could be handled by temporary repairs or by jury-rigging temporary lines. Several scenarios, however, could cause severe disruption because repairs would take a year or more. The work also concluded that the federal government could cooperate with industry groups to develop better contingency plans but that more radical actions, such as stockpiling spare parts, were not practical.

2.1.7.3 Work for FEMA

The Emergency Planning Group manages, in addition to in-house projects, all ORNL work done for the National Preparedness Directorate of FEMA. This includes work in the Economic Analysis Section of the Energy Division and in the Chemical Technology Division. These projects are summarized in Table 2.1.

Table 2.1. Work for FEMA—national preparedness

Project	Purpose	Principal investigator(s)	Status
State-of-the-art assessments			
Economic recovery	Summarize what is known about conditions for economic recovery from disaster	Hill Jones	Complete. German and Japanese experience suggests fast economic recovery is possible with functioning monetary system and free market system. Literature studies on international economics are under way
Postdisaster market development	Summarize what is known about reestablishing market economy after societal disaster	Rayner Cantor	Ongoing. Reviewing historical data and theories on how market exchanges and property rights are maintained after societal disaster. Chapters on light damage and maximum damage drafted
Shelter	Summarize what is known about sheltering civilians from effects of nuclear weapons	Chester	Complete. 1004 references. Blast shelter can be built for $300-$500/space in new construction. Could save over 90% of population in attack. Cost would be approximately 1% of DOD budget
Evacuation	Summarize what is known about civilian evacuations	Sorensen	Complete. Planning for evacuation of cities from natural disasters has become quite detailed
Emergency food and water	Summarize what is known about emergency supplies of food and water	Kerley	Complete. Plenty of food but generally maldistributed. Water supply depends on electric power. Current emergency plans require intact distribution system
Contaminated land	Summarize what is known about the hazards from and decontamination of radioactivity-contaminated or chemically contaminated land	Baes[a]	Complete. Pathways of radionuclides are well understood. Chemical contamination is much more complicated in the environment

Table 2.1 (continued)

Project	Purpose	Principal investigator(s)	Status
Warning	Summarize what is known about warning civilian population	Sorensen	Almost complete. Unless trained, most people require independent confirmation of warning in order to respond
Other projects			
Strategic food	Determine policy options for the development of a strategic food reserve	Bjornstad	Complete. Approximately 600 nation-days of food is available at harvest minimums; maldistributed. Relocation of Commodity Credit Corporation storage could provide 30-d minimum everywhere
Nuclear winter countermeasures	Identify modifications needed in current civil defense plans to cope with nuclear winter	Chester	Ongoing. Main problem of nuclear winter is loss of crop year. Can be survived by nations with livestock feeding industry and feed grain production. No direct threat to humans from low temperatures. Drought may be a problem
Expedient energy	Develop step-by-step instructions for expedient wood gasifier for automotive (including tractors) application	Zimmerman	Contract let for manual for expedient production of wood gasifiers to run gasoline engines during extreme fuel shortage. Prototype constructed; draft manual requires more work
Spontaneous evacuation assessment	Determine if Federal Highway Administration traffic sensors can be used to measure the extent of urban evacuation	Southworth	Ongoing. Work on analyzing records of traffic flows around Tampa Bay has begun
Health resources data	Adopt U.S. Department of Health and Human Services (HHS) data bases to FEMA's Integrated Emergency Management Information System	Vogt	Ongoing. Work has begun on adapting HHS data bases on emergency medical resources to FEMA's emergency management system
Hazardous chemicals	Analyze hazardous chemical release problem and how to cope with it	Byers[b] Holmes	Developing plans to cope with hazardous chemical releases. System of hazard ranking has been developed, and most highly hazardous chemicals have been identified. Agency responsibilities are being reviewed
Expedient antibiotic production	Determine how antibiotic supplies could be restored after a nuclear attack	Lee[b]	Development of planning guidance is under way for expedient restoration of antibiotic production. Candidate antibiotic has been identified. Critical problem is not fermentation but separation and purification of product
Emergency sanitation	Develop manual on emergency sanitation and manual on emergency supply of sanitation chemicals	Gutmanis[c]	Comments on emergency sanitation and water are being reviewed. Draft handbook on chemical supply for emergency sanitation is being reviewed

[a]Environmental Sciences Division.
[b]Chemical Technology Division.
[c]Subcontractor with Sterling Hobe, Inc.

Of the in-house projects, a state-of-the-art assessment of civil defense shelters was completed.[13] This treatise provides a key to 1004 documents that encompass most of what is known about shelter against nuclear weapons effects in the United States. The technical problems of protecting people against weapons effects are well in hand. The political problem of allocating the resources required (about 1% of the annual DOD budget each year) to protect the U.S. population has not been solved. Good blast protection for the 160 million people in the U.S. risk areas could be provided over 20 years in new construction for about $300–$500 per person. Fallout protection in new construction for the rest of the population could be provided for about $20 per person. Currently, the only blast protection for the U.S. population is shelter in basements or, if time permits, evacuation and expedient shelter construction.

An in-house study on emergency planning modifications to deal with nuclear winter is under way. It has been found that nuclear winter, if it should occur, does not present any qualitatively new problems for civil defense planning. Expected low temperatures are now believed to be, at worst, characteristic of a normal January, except occurring in summer. Drought may be a longer-term problem than expected. Planning modifications include (1) additional emphasis on storing one or more years' supply of food (unprocessed grains), (2) an assessment of the drought resistance of water supplies in reception areas; and (3) additional emphasis on taking ample winter clothing to a shelter or when evacuating, especially in hot weather.

2.2 TECHNICAL HIGHLIGHTS

2.2.1 Vibroacoustic Impacts of Hush-House Operations

A. J. Witten M. Lessen*

A hush house (Fig. 2.1) is a hangar-like structure designed for noise suppression during extended aircraft engine diagnostic tests. The walls of the structure are composed of acoustic baffles that attenuate sound but admit air flow into the building to provide cooling and prevent engine compressor stall. Exhaust gases exit the building via a muffler tube (the long tube extending out from the rear of the structure visible in Fig. 2.1), with the exhaust flow being deflected upward by a deflector ramp at the downstream end of the tube.

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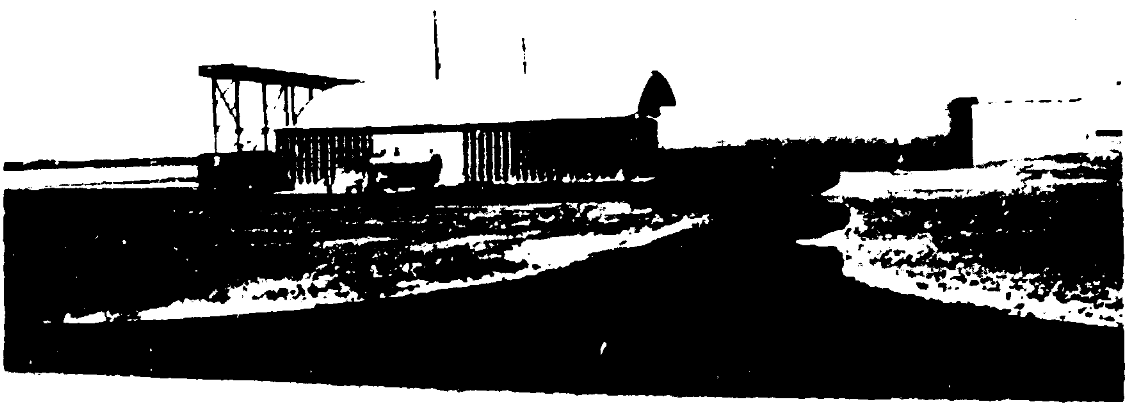

Fig. 2.1. Typical hush house.

Figure 2.2 shows an F-4 aircraft installed in a hush house for testing. Along with this configuration, tests can be performed in an engine-only mode with the engine mounted on a stand. Approximately 70 hush houses are currently in operation in the United States, and they have been proven effective at noise suppression.

*Consultant.

ORNL-PHOTO 5844-86

Fig. 2.2. F-4 aircraft installed in hush house for testing.

ORNL's involvement with hush houses is a result of problems encountered at several of the structures. Specifically, these problems involve significant vibrations induced in nearby buildings by low-frequency (subaudible) emissions from the hush houses. Our responsibility is to evaluate hush-house impacts as they relate to the siting of future hush houses as well as the siting of vibration-sensitive facilities, such as avionics labs, at both current and future hush-house installations. The study will aid in the development of detailed hush-house siting criteria. To support this effort, we are collaborating with the Air Force Geophysics Laboratory in (1) limited field studies directed at characterizing low-frequency hush-house emissions and (2) applied research to investigate the physical mechanisms that cause these low-frequency emissions.

Thus far, we have found that

1. low-frequency acoustic emissions from hush houses are the rule rather than the exception,
2. few problems have been reported because of the absence of sensitive receptors near existing hush houses,
3. realignments to modern fighter aircraft are expected to cause many more problems because of the need for vibration-sensitive support facilities,
4. the origins of low-frequency emissions from hush houses appear to result from a resonant mode of the hush-house structure which is driven by the aircraft engine exhaust flow, and
5. the principal wave energy propagation is through the air.

Figure 2.3 illustrates the suspected cause of the problem. Notice the engine exhaust flame. This exhaust flow is at a high Reynold's number and, consequently, should behave like a turbulent

ORNL-PHOTO 5843-86

Fig. 2.3. Engine exhaust flame inside hush house.

jet. If it did, the flame would quickly taper (narrow) with distance from the rear of the engine rather than maintain a uniform diameter as exhibited in the figure. This lack of tapering results from the fact that the energy in the exhaust flow which would go into the development of turbulence is preferentially removed by acoustic Cherenkov radiation. Acoustic Cherenkov radiation results from exhaust gas velocity that is sonic with respect to the speed of sound at the exhaust gas temperature. Because this exhaust gas is quite hot, it has a sound speed at least twice that of the surrounding air. Thus, the engine exhaust gas is moving at a speed that is supersonic with respect to the ambient air. Cherenkov radiation results whenever a particle stream or a fluid moves faster than the wave speed in the host medium. The resulting wave front resembles a shock cone.

The frequency of acoustic Cherenkov radiation depends on the engine exhaust velocity, exit diameter, and exit temperature. For these parameters, which are typical of fighter aircraft engines, the predicted Cherenkov radiation frequency is about 10 Hz, which is comparable to the radiation frequency observed at the hush house located at Luke Air Force Base.

Enhanced coupling of this wave energy to the environment is believed to occur as a result of a resonance of the muffler tube. Such a coupling will occur when the driving frequency (acoustic Cherenkov radiation) matches the natural (resonant) frequency of the structure. The fundamental mode (frequency) of the muffler tube will be one in which the associated wavelength is twice the length of the muffler tube. For the elevated sound speed within the muffler tube, this natural frequency has been calculated at approximately 10 Hz. Thus, it appears that this tube is tuned to the acoustic Cherenkov radiation emitted from the engine exhaust and that the tube is not functioning as a muffler but rather as an organ pipe.

Available vibroacoustic data at operating hush houses strongly support the theory proposed above; however, data are insufficient to provide absolute confirmation. If our belief proves correct, mitigation can be accomplished with a simple and inexpensive retrofit. The acoustic Cherenkov radiation is a stabilizing influence on the jet of exhaust gas. By providing a mechanism to promote a hydrodynamic instability, the stabilizing influence of the Cherenkov radiation would be negated, either substantially reducing the magnitude of vibrations or completely eliminating them. The exhaust jet could be destabilized by the superposition of a flow field that is known to cause turbulence in a laminar jet. Such necessary air flow already exists via the entrained ambient air drawn into the muffler tube by the ejector pump action of the engine. Modifying this flow so that it has the proper characteristics to promote an instability would be accomplished by means of flow-turning vanes mounted peripherally to the engine but not in contact with engine exhaust gas. These vanes could be fabricated and installed at each hush house at a modest cost.

2.2.2 Cumulative Impacts Methodology Development for the Owens River Basin

R. B. McLean

G. F. Cada*	N. E. Hinkle	C. H. Petrich	M. M. Swihart†
D. M. Evans†	G. M. Kondolf‡	B. L. Shumpert†	J. W. Webb*

A team composed of staff from the Energy and Environmental Sciences divisions developed a unique methodology[4] for assessing the impacts of multiple hydroelectric projects located in highly sensitive environments. This approach allows concerned citizens, developers, regulators, and the scientific community to define the importance of the resources at risk in light of past perturbations. For example, in evaluating the impacts to the Owens River Valley, California, public and agency input through scoping and technical sessions played a key role in identifying issues and defining what constitutes a significant impact of a given resource. A photoquestionnaire was also used to gather data from over 1100 people who use the recreation facilities, drive through the area, or reside in nearby communities. These data allowed the ORNL staff to quantify the quality of the resources and determine interactions among physical sites and among resources such as aesthetics, recreation, and the local economy.

In the next step of the methodology, ORNL staff evaluated the actual impacts of the proposed projects and compared them with the "significance" standard set by the public interaction. Impacts were mitigated, if possible, to an acceptable level. After mitigation, the multiple projects were evaluated for additional accumulative impacts resulting from synergistic effects and the economic viability of the project was determined (see Fig. 2.4). This approach hurdles many problems dealing with public acceptance, significance of impacts, and cumulative methodologies.

In summary, the impact analysis is a state-of-the-art methodology built on a base of ORNL's 13 years of experience in determining potential effects of energy development on the environment. The method maximizes public input, places impacts on diverse resources on a common scale,

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*Environmental Sciences Division.
†University of Tennessee.
‡Johns Hopkins.

ORNL DWG 86-13591

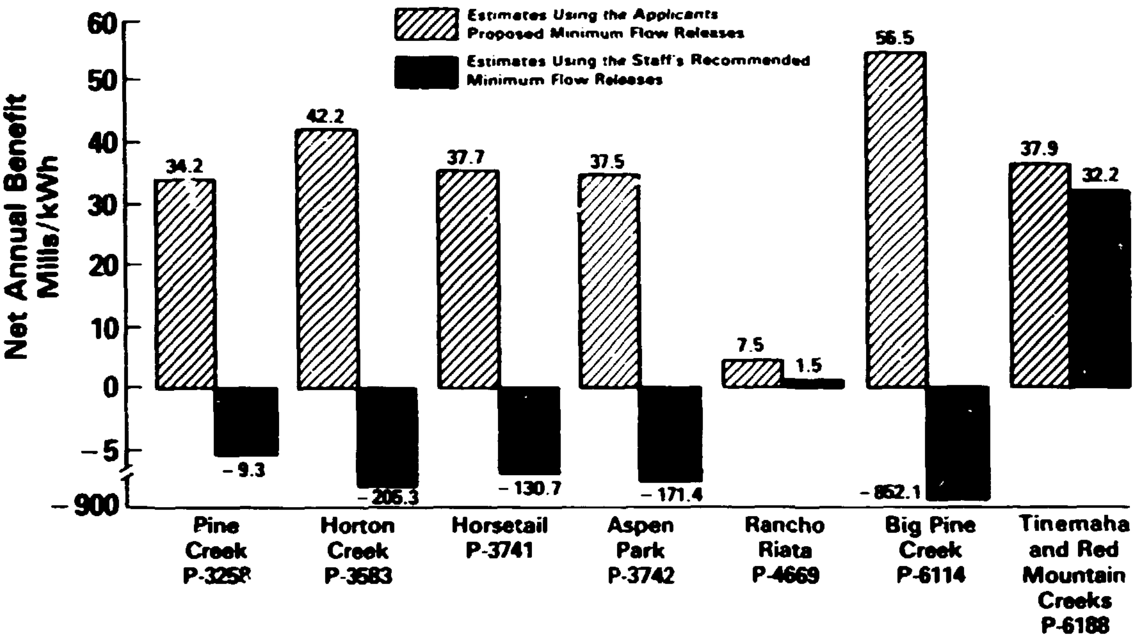

Fig. 2.4. Comparison of net annual benefits of seven hydroelectric projects in Owens Valley, California, before and after mitigative measures.

quantifies interactions among resources, and displays the bottom line in a simple matrix that can be used to demonstrate the best mix of projects and needed mitigation.

The first test for this method in the Owens River Valley of California resulted in a vote of confidence by FERC, which rejected five of seven proposed projects after a 50-year period during which they rejected only a single license on environmental grounds.

2.2.3 TOPS—Software Engineering and Transportation

S. S. Stevens*

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J. P. Loftis — J. Morris‡ — P. M. Spears — T. G. Yow

The Military Traffic Management Command (MTMC) operates the Personal Property Transportation Program of DOD at a large number of military bases throughout the continental United States and overseas. The MTMC uses manual methods for data storage and retrieval of 2000 forms and reports for management information. Although the labor-intensive operation costs

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well over $1 billion per year, imperfections in the system still create problems for thousands of armed services personnel whose household goods are mishandled in the shipping process.

In 1983, ORNL agreed to apply its expertise and impartiality to the design of an integrated, automated information management system to help MTMC better administer the program. In turn, MTMC agreed to ORNL's suggestion to use advanced software engineering techniques to supplement or supplant traditional DOD life-cycle development procedures. The resulting system, called the Transportation Operational Personal Property Standard System (TOPS), reached the prototype stage during 1986. The sponsors' patience and the ORNL TOPS team's early efforts are now being rewarded as the development of a standard system for the Army, Navy, Marine Corps, and Air Force accelerates.

Early efforts on TOPS focused on the selection of software engineering tools and vendor-independent off-the-shelf software. Tools chosen include Problem Statement Language/Problem Statement Analyzer (PSL/PSA)—a tool to facilitate a careful, consistent, and complete statement of a problem—and the ORACLE Corporation's data base management system (DBMS), a relational DBMS with particularly good application development facilities. In addition, an early ORNL decision mandated the development of TOPS under the UNIX operating system.

Project milestones attained in 1986 include design walk-throughs for each of the five modules of TOPS, development of a benchmark program for hardware selection, and public demonstration of a few early prototypes of two TOPS modules. It should be emphasized that the individual modules were developed in concert with the military personnel who in effect "lived" at ORNL and worked with our staff to define each module. The design walk-throughs featured presentations based on reports from the project PSA data base, and PSA analyses of the consistency of the data base. The benchmark and initial prototyping efforts were "coded" in ORACLE application programs directly from the detailed specifications contained in the PSA data base and serve as dramatic examples of the net time savings possible through front-loaded, design-driven software development.

Use of a term such as "coding" to describe implementation of computer functions in a fourth-generation language lends credence to the enormous productivity enhancement possible with modern techniques; the TOPS project is expected to require the equivalent of several hundred thousand "lines of code" in the traditional sense. Current efforts on TOPS are directed to prototype development for all five modules, and prototyping is expected to be almost complete by mid-1987.

2.2.4 Noise Analyses for and Public Acceptance of Air Force Projects

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NEPA's requirement is to assess impacts of major federal actions on the human environment. Therefore, ORNL's assessment of the impacts of Air Force low-altitude flight training (see Sect. 2.1.4.2) has focused considerable attention on human populations living in areas where these

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operations are conducted. Assessment is complicated because large areas are affected, population density tends to be very low, the training activities occur intermittently (people on the ground may see only a few aircraft daily), and previous research is not directly applicable to Air Force low-altitude training operations.

Typically, training operations occur either along corridors 600–1600 km long and 13 km wide or in military operation areas that vary in size but which generally cross several counties. Aircraft may fly as low as 100–125 m above ground level for extended distances to practice evading radar detection. A variety of effects on the human environment may result from low-altitude training operations, including concerns for safety, noise, intrusiveness, and disturbance to domestic animals.

Existing research has limited applicability to Air Force low-altitude training operations for several reasons. First, chiefly noise-related impacts are emphasized. Second, previous studies were conducted in densely populated areas in the vicinity of urban airports, where numerous flights occur daily. Third, the day-night average noise metric, devised to average noise levels over a year (with heavy penalties for night flying), may not be the most appropriate metric for the intermittent Air Force training flights.

Because of these factors, ORNL initiated preliminary research to identify the nature and extent of impacts to people living near Air Force low-altitude training activities. A semistructured interview protocol was developed, pilot-tested, and administered approximately 150 times under two low-level SAC routes in southeastern Colorado and northeastern Arizona, where B-52, FB-111, and occasionally the new B-1B bombers operate. These interviews have produced a number of interesting, although very tentative, findings, including the following:

- People favoring the training activities outnumber by several-fold those opposing the activities.
- Many people have no opinion about the operations and have little knowledge of their purpose.
- Compared with citizens of Colorado, almost three times as many people in Arizona have complained about the activities, at least among themselves.
- Noise is the primary concern in Arizona, whereas fear of crashes is the predominant problem in Colorado.

Counter to our expectations, no complaints were expressed over potentially harmful health effects or reduced property values, and a significant minority of people who support route operations have complained about them in some fashion.

This research will be expanded in conjunction with the GEIS on the Air Force's low-altitude training operations. It is anticipated that a model describing human effects under different flight parameters will be developed.

2.2.5 Chemical Stockpile Disposal Program NEPA Review

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Based on our past analyses of the health and environmental impacts of disposing of M55 rockets (see ORNL-6272),[14] the Army contracted ORNL to prepare NEPA documentation on the disposal of the nation's entire stockpile of chemical munitions and to provide associated support, including preparation of public information materials, arrangements for public scoping meetings and public hearings, and analyses of public concerns related to the disposal program. We completed, and the Army published on July 1, the draft EIS for the Chemical Stockpile Disposal Program.[15] In the next year, we are scheduled to prepare the final programmatic EIS and initiate preparation of site-specific NEPA documents for the eight Army installations currently storing chemical munitions (Fig. 2.5).

Our analyses considered four basic alternatives—on-site disposal; transportation and disposal at regional centers at Tooele, Utah, and Anniston, Alabama; transportation and disposal at a national center at Tooele; and continued storage (NEPA's no-action alternative). In each case, the disposal technology is high-temperature incineration followed by land disposal of hazardous solid wastes.

For each alternative examined and the activities associated with each (see Table 2.2), we considered the impacts of both normal operations and accident scenarios. The accident scenarios were based on probabilistic risk analyses performed by other Army contractors and were characterized in terms of chemical agent and munition types, source strength, mode of release, and probability. ORNL, in turn, identified potential areas at risk based on atmospheric dispersion and aquatic spill modeling. In the former case, we bounded the problems with two sets of potential meteorological conditions.

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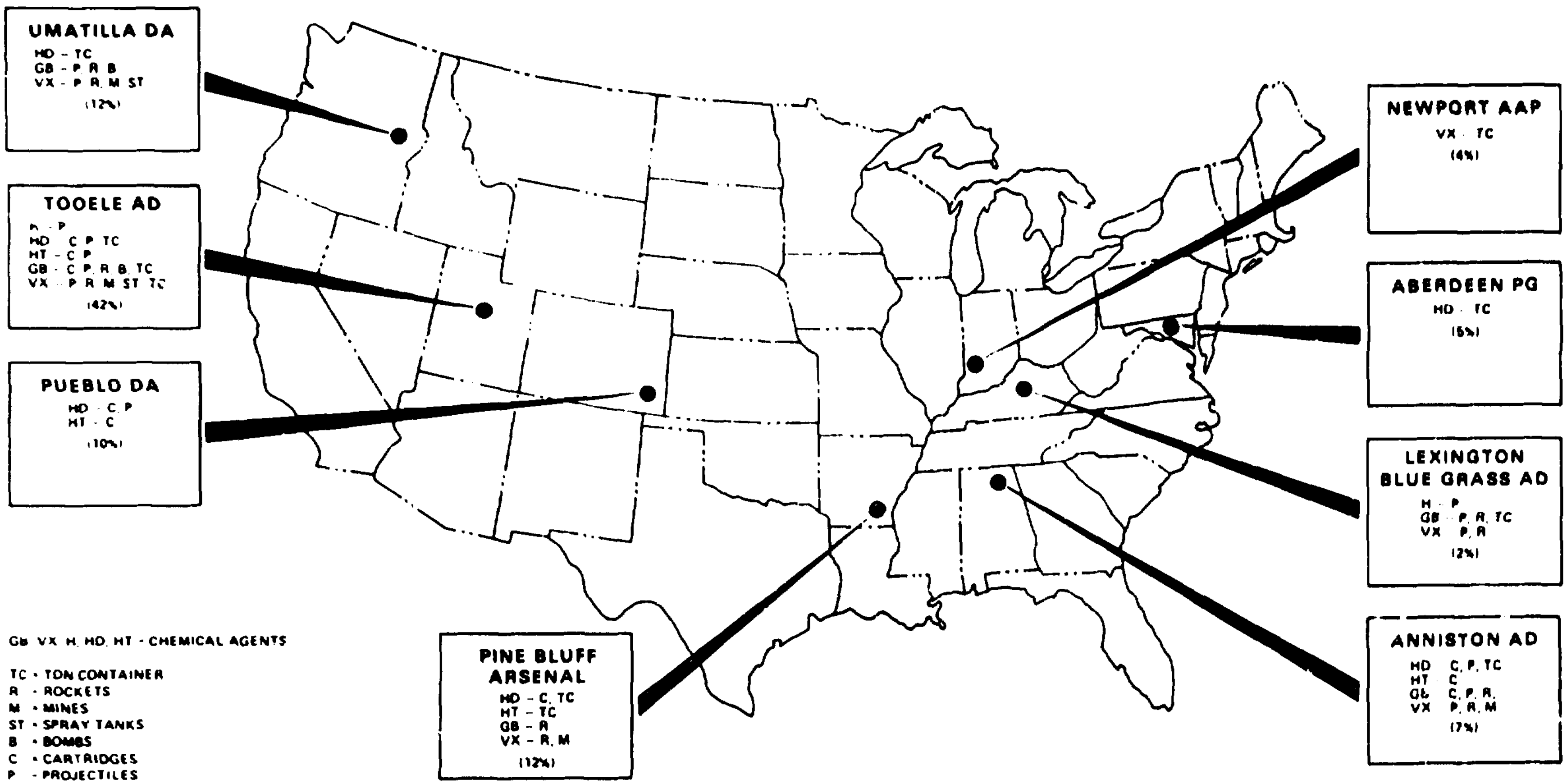

Fig. 2.5. Stockpile and M55 rocket distribution throughout the country.

Table 2.2. Activities associated with Chemical Stockpile Disposal Program alternatives

Activity	On-site disposal	Regional disposal centers	National disposal center	Continued storage
Short-term storage	x	x[a]	x[a]	
On-site handling and transport	x	x[a]	x[a]	x[b]
Off-site transport		x	x	
Plant operations	x	x	x	
Plant decommissioning	x	x	x	
Long-term storage				x

[a]At storage installations and disposal centers.
[b]For leakers.

The impacts of normal operations are, for the most part, expected to be insignificant, although some habitat would be destroyed during construction and subsequent operation. Most significant, however, are the impacts of the alternatives on emergency response capabilities, particularly in the area of chemical munition transport. In addition, citizens in communities adjacent to two of the installations (in Kentucky and Maryland) have expressed strong opposition to the on-site disposal alternatives; citizens near all of the installations are opposed to the continued-storage alternative.

The impacts of accidents are potentially spectacular. As noted in Table 2.3, fatalities are estimated to range from a low of zero in the event of a minor release in a sparsely populated area, to 1,900 if a major release occurred in a more densely populated area like Richmond, Kentucky, or Aberdeen, Maryland, to a high of 15,000 if a major release occurred in a metropolitan area during munitions transport. Impacts on other valued resources, including public water supplies, threatened or endangered terrestrial and aquatic biota, and human resources (quality of life, mental health, and other conventional socioeconomic resources), should vary with the size of the accident and the extent of fatalities.

The probability of accidental release during implementation of any of the alternatives was also examined in the draft EIS. Considering the size of the uncertainties surrounding these estimates, however, it was not possible to identify one alternative that was significantly safer or riskier than another.

Based on comments received during the public review and comment period, future efforts will concentrate on reconsideration of the risk analysis, consideration of new stockpile relocation alternatives, and enhancements to emergency planning. In addition, ORNL and the Army will determine whether an environmentally preferred alternative can be identified in the final programmatic EIS.

Table 2.3. Summary comparison of alternatives for accident scenarios

Alternative	On-site disposal	Regional disposal centers[a]	National disposal centers[a]	Continued storage
Impact category				
Air quality[b]	Lethal plume	Lethal plume	Lethal plume	Lethal plume
Surface water and groundwater[c]	Minor to major for spill into surface water	Minor to major for spill into surface water but potential increases due to transport	Minor to major for spill into surface water but potential greater than regional disposal center alternative	Minor
Aquatic biota	Varies with impacts to surface water	Varies with impacts to surface water	Varies with impacts to surface water	Varies with impacts to surface water
Terrestrial biota[d]	Minor to major	Minor to major	Minor to major	Minor to major
Human health[e]	0 to 1,900 fatalities[f]	0 to 15,000 fatalities[g]	0 to 15,000 fatalities[g]	0 to 1,900 fatalities[f]
Cultural/socioeconomic	Impacts quality of life, population, land use, emergency planning, and local economy	Impacts quality of life, population, land use, emergency planning, and local economy; in wide range of environments	Impacts quality of life, population, land use, emergency planning, and local economy; in wide range of environments	Impacts quality of life, population, land use, emergency planning, and local economy
Duration of impacts	Variable	Variable	Variable	Variable

[a]Because an accident is assumed to be possible anywhere along the transport route, impacts may be experienced in diverse environments anywhere between the storage and destination installations.

[b]The analysis assumed releases with no-death concentrations reaching 0.5, 1.0, 2.5, 10.0, 20.0, 35.0, and 50.0 km.

[c]Given their physical characteristics, agents VX and mustard are far more complicating in the event of a spill.

[d]Size and significance of impacts depend on size of accident, meteorological conditions, and affected species.

[e]Only fatalities arising as a result of acute exposures are quantified.

[f]The worst-case accidents for both on-site disposal and the continued-storage alternatives are the same. The calculations are based on the worst potential accidents (worst-case weather and highest population density), and the accident has a probability range of 10^{-5} to 10^{-7}, which represents a summation of all sites.

[g]The worst-case accidents for both the regional disposal centers and national disposal center alternatives are the same. The calculations are based on the worst potential accidents (worst-case weather and highest population density), and the accident has a probability range of 10^{-3} to 10^{-7}, which represents a summation of all miles traveled.

2.2.6 Evaluation of DOE's Weatherization Assistance Program

M. Schweitzer

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DOE's Weatherization Assistance Program disburses funds through its regional support offices and the states to assist local agencies in providing weatherization services for low-income families and individuals. During FY 1986, staff of the TASS Group conducted research for DOE to determine organizational, fiscal, and regulatory factors affecting the performance of local weatherization agencies.

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An extensive survey, administered to 200 randomly sampled local agencies, produced a response of 68%. Statistical analysis of these data was supplemented by a telephone survey of state and DOE support office staff involved with the weatherization program, as well as by site visits to selected local agencies. Final analyses have not yet been completed, but preliminary results of this study are available.

A comprehensive profile of local agency characteristics was developed covering seven major subject areas:

- program staffing,
- finance and resources,
- outreach and service delivery,
- installation procedures,
- program demographics,
- agency management, and
- services delivered.

Most agencies were relatively small, with annual expenditures of less than $450,000. On the average, agencies reported that they had to wait 30 d before receiving reimbursement for funds expended, with some agencies waiting as little as 7 d and others waiting as long as 90 d. About two-fifths of the respondents used in-house installers exclusively, while nearly as many used only contractors. For agencies using in-house installers, slightly less than one-fourth employed temporary workers. Finally, the majority of agencies evaluated their goal-related performance either monthly or quarterly. In general, goals established locally were evaluated more frequently than those established by the state.

Three measures of program performance were used in this study: (1) the cost per energy conservation measure installed, (2) the average cost per weatherized home, and (3) the number of homes weatherized in relation to the annual goal. Cost data were gathered for a variety of energy conservation measures, and great variation was found among agencies. For instance, the cost of installing a 13.5-kg (30-lb) bag of cellulose ceiling insulation averaged $7.51, with a low of $3.56 and a high of $21.25 reported. The cost for a complete home weatherization averaged approximately $1200, with over 85% of the agencies reporting a mean expenditure per home between $700 and $1900. The number of homes weatherized by each agency in relation to its previously established goal ranged from a minimum of 0.6 to a maximum of 1.8, with almost 70% of the agencies clustering around the 1.0 mark.

A series of organization-theoretic hypotheses was tested to relate agency characteristics to the previously mentioned program-performance measures. In addition, local weatherization directors were asked open-ended questions concerning their perceptions of factors influencing program outcomes. The findings and associated recommendations are as follows:

1. Frequent evaluation of local goals is associated with lower costs per unit weatherized. Therefore, it is recommended that states encourage their local agencies to subject their goals to frequent review.
2. The use of established client selection criteria is correlated positively with high goal attainment. If client selection is based on social need rather than dwelling unit characteristics, costs per energy conservation measure installed are lower. Accordingly, the use of appropriate client selection criteria is recommended.

3. The use of contractors to weatherize homes is associated with higher costs per energy conservation measure installed. Therefore, it is recommended that agencies using contract labor examine their activities to determine where more efficient operations could result from the use of in-house crews.
4. Delays in state reimbursements of local agency expenditures are associated with higher costs per energy conservation measure installed and are also seen by local agencies as a major factor in reducing program performance. It is recommended that DOE examine the interaction of state and local operating practices contributing to these adverse impacts.
5. A substantial majority of all local respondents reported that the proportion of their total funding allocated for administrative expenditures was insufficient. Within the restricted range of expenditure patterns represented by the agencies studied, however, no statistical evidence was found to support a relationship between program outcomes and spending limits. Still, because of the self-reported dissatisfaction, it is recommended that DOE study and reconsider the current statutory limit on administrative expenditures.

2.2.7 Analyses for Developing a Low-Level Waste Disposal Facility on the Oak Ridge Reservation

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D. W. Lee

The IAAS has been involved in the siting, characterization, and performance assessment of LLW disposal facilities on the Oak Ridge Reservation as part of the Low-Level Waste Disposal Design, Development, and Demonstration Program. During FY 1986, IAAS personnel performed a site-selection study and a preliminary pathways analysis for a proposed tumulus-type waste disposal demonstration. The tumulus is a low-level radioactive waste disposal facility made of concrete and partially above the land surface, with engineered cover and leachate collection systems and earth cover.

The site-selection process used a hierarchy of exclusionary criteria to eliminate from consideration areas having undesirable characteristics for development of the tumulus. In general, the site-selection process followed the same procedures developed by IAAS staff in a previous site-selection study performed to identify candidate sites for shallow land burial of LLW on the Oak Ridge Reservation. Three tracts of land within which candidate tumulus sites could be located were identified in Bear Creek Valley. All three tracts are underlain by bedrock of the Conasauga Group, which is composed principally of calcareous siltstones and shales. The preferred site, shown in Fig. 2.6, was judged superior to the other two areas on the basis of topographic conditions.

The pathways analysis of the potential exposure to individuals and the public from the disposal of radioactive materials in a tumulus at the Bear Creek site was performed. In previous analyses, the tumulus concept had been considered for application on the West Chestnut Ridge site where the available dilution capacity in surface water for the release of radionuclides is limited. At the Bear Creek site, the available dilution capacity is considerably larger and provides a greater degree of protection from exposures to the inadvertent intruder. The potential exposure to the public is small for a tumulus located at the Bear Creek site or the West Chestnut Ridge site.

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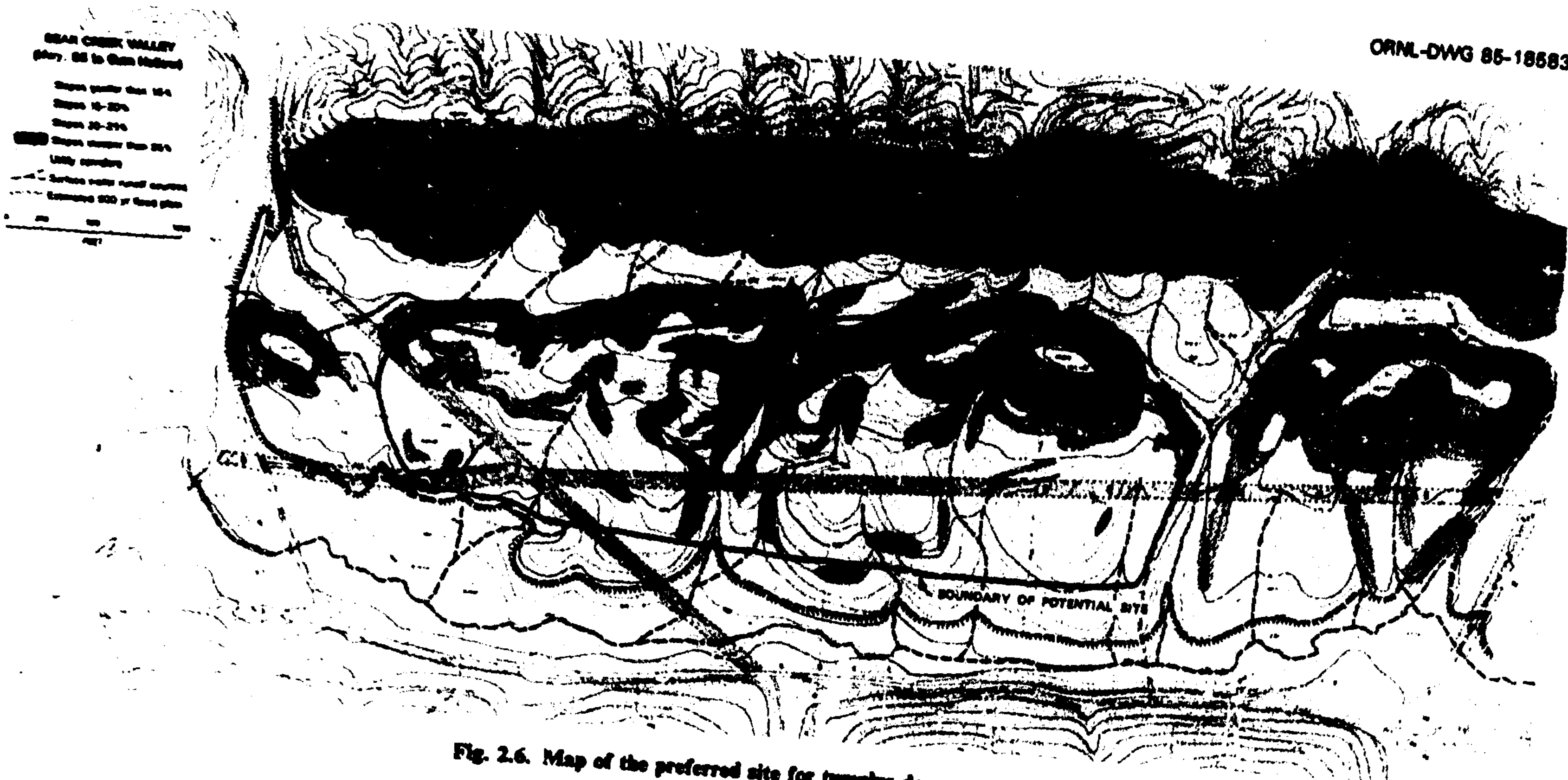

Fig. 2.6. Map of the preferred site for tumulus demonstration.

2.3 RESEARCH UTILIZATION

Work performed by the IAAS and applied research results are valuable not only to our sponsors but also to other organizations. The members of the Section present papers at conferences and professional meetings and report results to our program sponsors. While the research utilization of the work carried out by IAAS can best be characterized in terms of information transfer, we also participate in technology transfer. Examples of such transfer are as follows:

1. The EPA has requested permission to use the Oak Ridge Emergency Response Plume Model[14] as the best tool available to communities requiring emergency preparedness and response capabilities. The EPA plans to provide the code to communities requesting assistance in this area.
2. The Population at Risk Analysis methodology, developed by Hillsman et al., received a citation award from the 1986 Applied Geography Project Awards Program from the Association of American Geographers.
3. The software engineering modules designed for the TOPS project (Sect. 2.2.3) are being transferred to DOD.

A large portion of our work involves the preparation of NEPA documents in support of a sponsor's need to inform the public of the environmental consequences of a major federal action. The analyses contained in such documents, reflecting the state of the art, operate as a transfer mechanism to both the public and scientific community. The non-NEPA portion of our work, such as work for FEMA, is also used to transfer technical information. In particular, the work on emergency preparedness and evacuation planning is of great value not only to our sponsors but also to the scientific community. That ORNL is becoming a center of expertise in these areas is an accepted fact.

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3. Energy and Economic Analysis Section

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B. L. Bush   R. J. Friar

3.1 INTRODUCTION

The research agenda of the Energy and Economic Analysis Section has been diverse both in terms of research methodologies used in the analyses and in terms of topics. The research groups have addressed issues ranging from the externalities associated with the construction of large installations to understanding the necessary and sufficient conditions for markets to exist in a postdisaster setting. The Section's analytical approach is multidisciplinary in nature, although the principal focus is on economics and geography. The Section also works closely with other divisions at the Laboratory and continues to play a strong role in the Energy Division's international programs, with in-country activities involving Costa Rica, Pakistan, Bangladesh, and Haiti.

Administratively, the Section is divided into four groups: the Energy and Technology Economics Group, the Resource and Environmental Economics Group, the Transportation Group, and the Resource Analysis and Planning Group. The activities of each group are reported in Sects. 3.1.1–3.1.4. The chapter also reports several technical highlights of FY 1986 (Sect. 3.2).

3.1.1 Energy and Technology Economics Group

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S. M. Cohn	L. J. Hill
T. R. Curlee	C. R. Kerley

FY 1986 was the start of a transitional period for the Energy and Technology Economics Group which saw several changes both in group staff and responsibilities. The major change was the assignment of the Energy Information Administration (EIA) Program to the group, under the direction of D. J. Bjornstad and the assistance of C. B. Foust. In addition, a series of economic impact analyses has been consolidated under the leadership of C. R. Kerley. These changes are indicative of the increasing integration of group activities with other portions of the Division. Research activities were structured around three areas: (1) energy, (2) technology and

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information, and (3) economic impact analysis. Support from the Department of Defense (DOD) increased significantly during the year, and this growth is expected to continue.

Research on energy topics spanned a considerable range. The first phase of a major study of public power in the United States was completed.[1] This study provided a detailed analysis of regulation and comparative financial performance in the U.S. electric utility industry by ownership type. Estimates of short-run cost functions by ownership type were completed. These formed the basis for a second-phase research effort aimed at providing long-run cost-function estimates by ownership type in the industry. This work was supported by the Electric Power Division of the EIA. A related effort[2] focused on the transmission and distribution of electricity to reestimate and reconsider a number of relationships contained in the EIA National Coal Model and Intermediate Future Forecasting System. Out of this study came a new data base for the examination of transmission and distribution costs and a series of recommendations of ways for EIA to strengthen this data base. The final EIA study conducted during the year was a continuation of oil vulnerability research. In this effort, documentation was prepared for the Petroleum Allocation Model. Relatedly, an article that described a method for monitoring the viability of the U.S. uranium industry was published.[3] Finally, a report[4] addressing the impact of crude oil price changes on the foreign debt of African nations was prepared (see Sect. 3.2.2).

Research on technology and information issues increased over the period. A major study for the Energy Conversion and Utilization Technologies (ECUT) program on plastics recycling (see Sect. 3.2.3) culminated in the publication of a book and related articles.[5–7] Other research for ECUT included the publication of a report that considered the energy conservation potential of innovative methods of materials processing.[8] In addition, work leading to a second book on corrosion is progressing.

Research on information systems increased during the past year. After several iterations, a paper describing conceptual aspects of success or failure of information systems within organizational structures has been completed.[9] A questionnaire for gathering information needed to test the hypotheses raised by the paper has been designed and has undergone pretesting. This work will expand during the next year as the questionnaire is applied to several new information systems. In addition, a cost-benefit analysis of options in acquiring information support services through alternative contractual arrangements was undertaken.

The major economic impact analysis work undertaken by the group was the Economic Resource Impact Statement project. This effort, undertaken on behalf of the Air Force, resulted in the development of a handbook of procedures to account for local procurements, construction, and military income expenditures in an Economic Impact Region (EIR) surrounding an Air Force base.[10]

Expenditure levels in the EIR are used to estimate the private sector employment supported by the military activity. These estimates are published annually for each base and are used by planners and others when considering the impact of the base. As part of this effort, estimates of spending by different types of military personnel (i.e., living on or off base, regular or civilian) were estimated.

Finally, a significant effort was expended in managing the EIA program. Individual research efforts are reported here through line organizations, but one program, the independent expert review effort conducted in the group, is noteworthy. This program provides reviews of EIA documents by enlisting the services of leading scholars throughout the nation, as well as at ORNL. Ten such reviews were performed during the past year.

3.1.2 Resource and Environmental Economics Group

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The Resource and Environmental Economics (REE) Group is involved in diverse economic analysis activities that share the common purpose of analyzing, evaluating, assisting in, and informing about resource and environmental policy decisions. Major programmatic support for the group is in the areas of (1) biomass and traditional energy supply studies for the Department of Energy (DOE), (2) economic impact analyses for the DOE Office of Environmental Analysis (OEA) and the Federal Emergency Management Agency (FEMA), and (3) international economic/energy studies for the U.S. Agency for International Development (AID). These activities are described below.

Economists from the REE staff have continued to provide economic analysis and management support in biomass research to the Environmental Sciences Division. Major efforts this past year have been in the continuation of the Herbaceous Energy Crops Program. Analyses of field experiments have provided initial production cost estimates for five regions and seven crops. The estimated price of production, using current technology, for the various energy crops ranged from \$49/Mg to \$60/Mg. It is estimated that technology available by the year 2000 could lower these prices by more than one-half. In addition to the field production cost, a study of conversion processes showed that lowering of transportation costs and alcohol conversion costs is a key factor in providing alcohol fuel at competitive prices. The transportation cost, which varies depending on specific technology and plant size, ranges from \$1.70/Mg to \$16.64/Mg. Opportunities for increasing crop yields and conversion efficiencies, as well as for lowering transportation costs to improve the potential competitive advantage of these biomass fuels, are being investigated in current analyses. A more detailed discussion of the biomass studies is presented in Sect. 3.2.5.

In work sponsored by the U.S. AID, REE staff have been evaluating the potential market for coal briquettes as a domestic and commercial fuel in two developing countries, Haiti and Pakistan. The fuel would be a substitute for charcoal and firewood in these countries, helping to reduce the pressure imposed by dwindling wood resources.

The assessment in Haiti has been completed, with market estimates of charcoal consumption in the Port-au-Prince area exceeding 100,000 t/year. The economics of mining Haitian lignite and producing briquettes were compared with an imported coal option and with existing fuels—charcoal and kerosene. While one of Haiti's lignite deposits is very remote and appears to possess coal of such low quality that it could not economically compete with charcoal, a second deposit holds some promise. The imported coal option also seems to be a potential solution to Haiti's growing deforestation problem.

As part of the AID program, REE staff have also contributed general economic and energy data and modeling support in the Haitian effort to formulate a five-year energy plan. A variety of

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‡Dual capacity.

economic and energy data series for Haiti was collected and assembled in a personal computer data base system for use by staff of the Haitian Ministry of Mines. REE staff also developed an energy/economic planning model to facilitate the Ministry's analysis of possible energy/economic interactions. This effort resulted in the construction of a Computable General Equilibrium Model for Haiti (see Sect. 3.2.1).

A coal briquetting assessment is also in progress for Pakistan. Already completed is a major nationwide fuel-price survey that will identify the most likely markets for conventional fuels in Pakistan. Surveys on residential, commercial, institutional, and light-industrial fuel consumption are planned. These surveys, combined with the information on price collected this year, will be used to provide estimates of the potential markets for coal briquettes. Also planned are a consumer acceptance test on the use of coal briquettes in residential and commercial sectors and a survey to determine private sector interest in manufacturing and marketing coal briquettes.

Research on economic and institutional factors related to nuclear power production has continued this year. A recent REE effort, sponsored by DOE EIA, included a review of prudency hearings to examine the various ways in which public utility commissions (PUCs) are monitoring utility management processes and to identify the important common issues that have emerged across jurisdictions. The data upon which the analysis was based were taken from management audit reports, records of PUC prudency hearings (including commission findings and orders), and public staff reports that were obtained for more than one-half of the states with nuclear power plants. Issues that were identified as most important by the analysis include (1) utility responsibility for the prudency of subcontracted construction or maintenance work, (2) documentation of changes in the construction process and estimating practices, (3) equipment failures and the quality assurance/quality control program, (4) shortages of skilled workers and critical components, (5) the role of experience and training, and (6) the level of utility attention paid to interim construction decisions.

In the environmental and economic impacts area, REE staff members have been involved in the continuation of past programs as well as in the development of new research directions. The REE staff continue to provide assistance for OEA in a joint effort with the Decision Systems Research Section. Group research efforts for OEA this past year have continued the development of basic industrial and regional economic data bases for use in a personal computer environment. In addition, two major analyses were conducted: the regional trends of energy consumption and the shift in industrial location of energy-intensive manufacturing during the late 1970s.

The OEA Regional Energy Consumption Trends project is directed toward developing microcomputer capability to analyze historical trends and provide a simplified baseline regional forecasting system for use by OEA staff. The past year's efforts were focused on residential energy consumption trends for electricity and distillate fuel. An analysis data base was constructed using the EIA's State Energy Data System and the companion State Energy Price System, combined with the ORNL State Level Electricity Demand data base. With the combined files, a cross-section/time-series energy demand model was estimated using the Statistical Analysis System Package. Examination of recent historical trends in electricity consumption yielded somewhat surprising findings. Although it has been recognized that total fuel consumption has been declining as a result of higher energy prices and that a concurrent shift toward electricity consumption relative to other fuels has also occurred, the size of these shifts proved startling. Table 3.1 indicates the change in electricity's share of residential use from 1970 to 1981 for the ten federal regions. The electricity share increased because per capita use of electricity rose while total energy use declined. This difference in relative change is shown in Table 3.2.

Table 3.1. Regional residential energy consumption trends
(Electricity consumption increased in share for all regions during the 1970s.)

Region	Electricity share (%) of total energy	
	1970	1981
New England	10.6	18.7
New York/New Jersey	10.4	15.6
Mid-Atlantic	14.5	24.3
South Atlantic	33.2	52.3
Midwest	12.2	18.7
Southwest	23.0	41.2
Central	13.8	25.1
North Central	12.6	25.3
West	18.3	28.5
Northwest	40.4	62.0

Table 3.2. Growth rates in residential energy consumption from 1970 to 1980

Region	Average annual growth (%)		
	Per capita consumption		Total consumption
	Total energy	Electricity	Electricity
New England	−2.8	2.4	2.8
New York/New Jersey	−1.6	2.1	2.0
Mid-Atlantic	−1.2	3.5	4.0
South Atlantic	−1.6	2.6	4.6
Midwest	−1.4	2.5	2.8
Southwest	−2.1	3.3	5.5
Central	−2.0	3.6	4.0
North Central	−2.2	4.4	6.6
West	−2.1	2.1	4.2
Northwest	−1.2	2.8	4.9

The study investigates further the influence of population and income growth as factors in the regional electricity demand changes.[11] The average annual per capita growth rate of total residential energy use fell in all regions, while electricity per capita growth rates increased in all regions. The total consumption of electricity also grew at substantive rates during the 1970s. In several regions (e.g., South Atlantic, Southwest, and West), the total growth rate was significantly greater than the per capita growth rate because of the demographic and economic growth taking place in those regions. In the New England and New York/New Jersey regions, on the other hand, the total electricity growth only matched the per capita growth, indicating that the primary growth for electricity resulted from price and income effects. This result reflects the stable populations (i.e., sluggish growth) in these regions during the period. In the next year, REE staff will conduct a similar study of industrial energy consumption trends.

A study of the regional shift in share of the manufacturing sector for the 1975–80 period has also been completed for OEA. Of special concern in the study was the identification of the different regional shifts in the energy-intensive vs the non-energy-intensive industries. Nationally, total manufacturing employment grew by 11.6% during the period. However, the less-energy-intensive industries (growth rate of 12.7%) fared considerably better than the energy-intensive ones (growth rate of −1.2%). The study also finds that substantive shifts in industrial location occurred during the period and that the state impacts are quite different for the energy-intensive and non-energy-intensive industries. For the energy-intensive industries, the southern and southwestern states (Alabama, Arizona, Arkansas, Georgia, Kentucky, Nevada, Oklahoma, Texas, Virginia, and West Virginia) show a positive advantage in growth, while the "rust-belt" states (Delaware, Illinois, Michigan, New Jersey, Ohio, Pennsylvania, and Vermont) show a negative advantage. The study will continue using more recent data to investigate whether these trends have changed as a result of the post-1981 decline in oil prices and to confirm the anecdotal evidence of the "high-technology" thrust to the two-coast economy.

Recently, a renewed interest in comprehensive regional impact modeling has arisen in a variety of agencies, with primary support for REE coming from FEMA. Over the past two years, REE staff have been developing an integrated regional and national impact analysis system to provide decision support capability for FEMA's disaster assessment program. The Integrated Management and Economic Analysis System (IMEASY) prototype was completed this year and installed on FEMA's computer for testing. The primary design goal for the prototype was to develop an interactive system that would provide the nontechnical user with both an assessment capability and a quick-response capability. A key innovation in the IMEASY prototype was the integration of facility-specific information (identified by geographical coordinates) with traditional regional aggregate information. A user can prepare a regional economic impact analysis for either a natural-disaster or human-caused-disaster scenario by specifying the spatial extent of the disaster. The IMEASY system then uses the spatially located facility information with other regional data series to provide local, regional, and national estimates of the direct and indirect impacts of the disaster on potential economic output. The data bases and analysis tools can, of course, be used in a nondisaster setting to provide quick regional economic profiles for any user-defined region composed of counties.

In another area of FEMA-supported research, the REE group has recently examined the exchange, distribution, and market systems after a social cataclysm to determine what social conditions would have to exist for rational mechanisms of distribution and exchange to function. The research examines novel adaptations of familiar free-market arrangements which may arise according to local circumstances to maintain trust between agents or to substitute confidence in an institution that will enforce contracts when trust is missing.

The group also oversaw managerially the completion of the two-year effort to develop a commercial sector model for the Bonneville Power Administration (BPA) Division of Power Forecasting, located in Portland, Oregon. In the ORNL Commercial Reference Building Energy Demand (CRBED) Model, a classical programming approach is used to depict the combination of end-use and process technologies chosen in new commercial buildings. The new-structure simultaneous selection process applies to choice of building envelope efficiency, heating equipment and fuel, distribution system type, ventilation fan motors (if required), cooling equipment fuel and type, and lighting equipment type. The simultaneous choice components also produce "shadow prices" that may be associated with the cost of conserved energy for different programmatic initiatives. A particular combination of the processes and end uses cited above constitutes a reference building, for which an operating cost is predicted. The CRBED model improves upon the

Synergic Resource Corporation (SRC) model—a descendent of the original Oak Ridge Commercial Model developed in 1976—which BPA used after substituting for the SRC Heating, Ventilation, and Air Conditioning (HVAC) submodel. The HVAC submodel has been replaced by two components: (1) a technology choice submodel, which involves the selection of energy efficiencies based on a live-cycle-cost minimization simulation; and (2) a fuel-and-equipment choice submodel, which translates the information from technology choice into market shares (the percentages of building floor space) by fuel type for each end use, by building type, and by building vintage. The CRBED model was completed, transferred, and tested on the BPA computer system last year, and the model documentation is in the final stages of completion.

3.1.3 Transportation Group

D. L. Greene*

S. M. Chin	M. C. Holcomb	B. E. Peterson
S. D. Floyd	P. S. Hu	F. Southworth
I. G. Harrison	R. N. McGill	

The Transportation Group conducts research and development (R&D) on a wide range of transportation issues for sponsors in DOE, the U.S. Department of Transportation (DOT), and DOD and for other federal agencies such as FEMA, AID, and the General Services Administration. The group's R&D is directed toward three vital themes:

1. energy conservation program and policy analysis,
2. modeling tools for planning and management of transportation systems, and
3. large-scale transportation planning and management information systems.

Over the past year, significant efforts continued in each of these areas, with the group leading several projects and acting in collaboration with the Chemical Technology and Engineering Technology divisions on others.

The group's work in energy conservation and policy analysis is primarily for DOE's Office of Transportation Systems (OTS) and Office of Policy Integration. The Federal Methanol Fleet demonstration project completed its first year of operation. The fleet of methanol cars at Lawrence Berkeley has been in operation for over a year and the cold weather test fleet at Argonne National Laboratory has just begun (see Table 3.3). Associated with the methanol fleet activities and under the auspices of the Alternative Fuels Utilization Program, ORNL and the Ford Motor Company are negotiating a subcontract under which Ford will develop novel cold-starting technology for methanol-fueled vehicles. Poor cold-starting capability is recognized as one of the last great technological barriers to the widespread introduction of methanol. The group also successfully completed its management of DOE's short-lived Ridesharing Program with the testing and dissemination of a unique high-occupancy vehicle (HOV) simulation model to assist local governments in planning and designing HOV lanes.

A microcomputer spreadsheet-based Heavy Truck Technology Forecasting and Energy Demand Model was constructed for ORNL's Engineering Technology Division in support of their

*Group Leader.

Table 3.3. Lawrence Berkeley Laboratory fleet data—November 1, 1985, to October 31, 1986

Vehicle ID	Total trips	Total distance (km)	Average distance/trip (km)	Average fuel economy (km/GJ)
		Methanol Cars		
E-36753	197	13,378	67.8	270
E-36754	179	13,312	74.4	277
E-36755	202	10,968	54.2	275
E-36756	221	11,150	50.4	279
E-36757	229	10,174	44.5	258
Five-car totals	1,028	58,982	57.4	272
		Gasoline Cars		
G-92563	234	25,707	109.9	305
G-92580	311	27,331	87.8	283
G-92611	313	21,774	69.6	274
G-92709	135	23,586	174.7	315
G-92771	311	20,528	66.1	289
Five-car totals	1,304	118,926	91.2	292

lead role in planning DOE's Heavy Duty Vehicle R&D Program. This model allows an analyst to project the market penetration of engines and energy-conserving equipment on new heavy trucks in three weight classes. Based on historical trends and his own judgment, the user can calculate the impact of the new technology on energy use by all heavy trucks.

The group also conducted analyses of the economic effects on consumers and manufacturers of the Corporate Average Fuel Economy Standards for automobiles and light trucks. A new computer program was written to estimate the effects of changing vehicle characteristics related to fuel economy on consumer's surplus (a dollar measure of satisfaction).[12] Using data from 1978–85 and estimates of the marginal valuation of vehicle characteristics from the economic literature, the net effects of engineering and design changes, improved fuel efficiency, and price increases resulting from these changes were estimated to be approximately zero (see Sect. 3.2.6).[13] Finally, the group assisted AID in the design and analysis of a taxi and bus energy conservation demonstration project in Costa Rica. The results proved for the first time that short-term energy conservation measures could increase efficiency in actual operations in a less developed country.[14] Through driver training and simple maintenance practices, taxi and bus operators achieved savings of 5–10%.

The group continued to develop new modeling tools for planning and managing transportation systems. In addition to the HOV simulation model mentioned above, an improved simulation model for analyzing traffic flows and bottlenecks during evacuations was developed and used for the Army Corps of Engineers to evaluate possible evacuations in the event of dam failures.[15] A second project, to model population evacuations for FEMA, is leading to a prototype, real-time, electronically based traffic counting system for use during hurricanes or more protracted emergencies.[16] For the U.S. Armed Forces Command, work continued to expand the capabilities of the Mobilization Automated Support System for routing and scheduling convoys during a mobilization. This model uses a novel algorithm to ensure that convoys are routed efficiently, arrive on time, and do not conflict with other movements. The group completed its analyses of the Federal Highway

Administration's (FHWA) vehicle travel forecasting needs and current modeling capabilities and has begun implementing recommendations in the revision of FHWA's Highway Traffic Forecasting System.[17] In collaboration with a visiting researcher from the Ministry of National Economy, Tunisia, a spreadsheet-based vehicle stock model was developed to evaluate energy policies directed at changing the efficiency, fuel type, size, or composition of the vehicle stock in less developed countries.[18] This model served as the basis for the previously described Heavy Truck Forecasting Model developed for DOE/OTS.

The group's third major research thrust is the improvement of transportation information systems for planning, policy analysis, and system operation. The ORNL MPG and Market Share Information System, the only current source of monthly fuel economy estimates, continued to be improved and updated.[19] FY 1986 saw the publication of the system documentation and user's guide, as well as the extension of the data base back to 1976 for most vehicles, and the completion of a study of factors affecting domestic and imported vehicle market shares. Edition 8 of the *Transportation Energy Data Book*[20] was published early in the year, and Edition 9 was prepared in draft form by year's end.

A new project was begun with the FHWA to design a prototype on-line access system for the statistics that FHWA collects about the nation's highways and to link these to the national highway network developed by ORNL for the U.S. Army. The objective is to provide modeling and graphical display capabilities as well as on-line access to the data. The ORNL highway network forms the key link in this planned system, connecting the data systems, models, and graphics. The FHWA Integrated Traffic Data System Graphics project is near completion. This personal-computer-based system provides local traffic engineers the capability to manage traffic data, execute a battery of simulation and optimization models, and prepare and maintain required charts and diagrams by using a single user-friendly system.

3.1.4 Resource Analysis and Planning Group

R. Lee*

S. Das	D. A. Trumble
T. M. Dinan	R. M. Wright

The research of the Resource Analysis and Planning Group focuses on planning and policy issues related to the supply of and demand for resources. Emphasis is also given to analytical methods and models, particularly econometric and statistical analysis, computational methods in microcomputer environments, applied microeconomic theory, and operations research. Over the past year, studies were completed on flood hazard assessment; energy conservation and the demand for electricity; the supply of petroleum products, uranium, and electricity; and the distribution of materials.

A study for the U.S. Army Corps of Engineers developed several computational methods to estimate the economic damages and loss of life resulting from hypothetical dam-related flood events. Interactive microcomputer software (called DAMAGE), written by S. Das, combined

*Group Leader.

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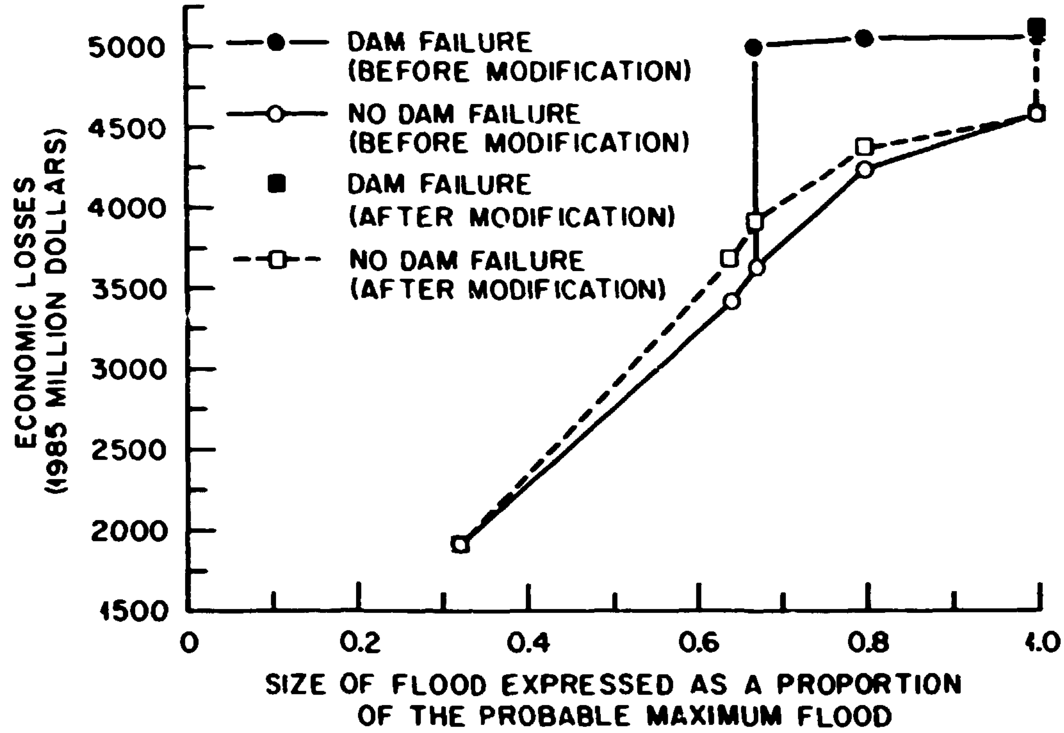

Fig. 3.1. Estimated economic losses in hypothetical dam-related flood events for a New Mexico case study. Note: Modification consists of raising the top of the dam by 3 ft and widening the spillway by 1000 ft.

economic data, flood elevation estimates, and flood depth-damage information to compute economic losses. An example of the results is given in Fig. 3.1, in which the estimated economic losses are compared for different flood events (expressed as proportions of the probable maximum flood), dam failure and nonfailure scenarios, and before and after modification of the existing dam. The solid line in the figure represents the estimated economic losses under different flooding scenarios with the existing dam, which was designed to hold a flood that is 67% of the probable maximum flood. Any flood exceeding that threshold may cause the dam to fail. With a failure, the estimated losses are represented by the upper solid line. If the dam does not fail beyond the threshold flood, the losses are represented by the dashed line. Because the modification is intended to handle the probable maximum flood, a failure may occur at that level (the vertical portion of the dashed line) but not at any lower level. In general, dam modification entails a wider spillway, with greater flood discharge and damage for most flood scenarios; but modification reduces the probability of dam failure and its catastrophic impacts.

Estimates of loss of life in dam-related flood events were developed by R. Lee, D. A. Trumble, and other division staff. Empirical analysis of past floods revealed that the chances of human death from a flood can be estimated by a group logit model in which the probability of death for a given individual is greater with little warning time, in less populated areas, with greater flood depths, and in areas that had experienced flooding in the last ten years. Some sample estimates for a case study in the southwestern United States are given in Fig. 3.2. The interpretation of this figure is analogous to that for the previous figure. A proposed dam modification involved widening the

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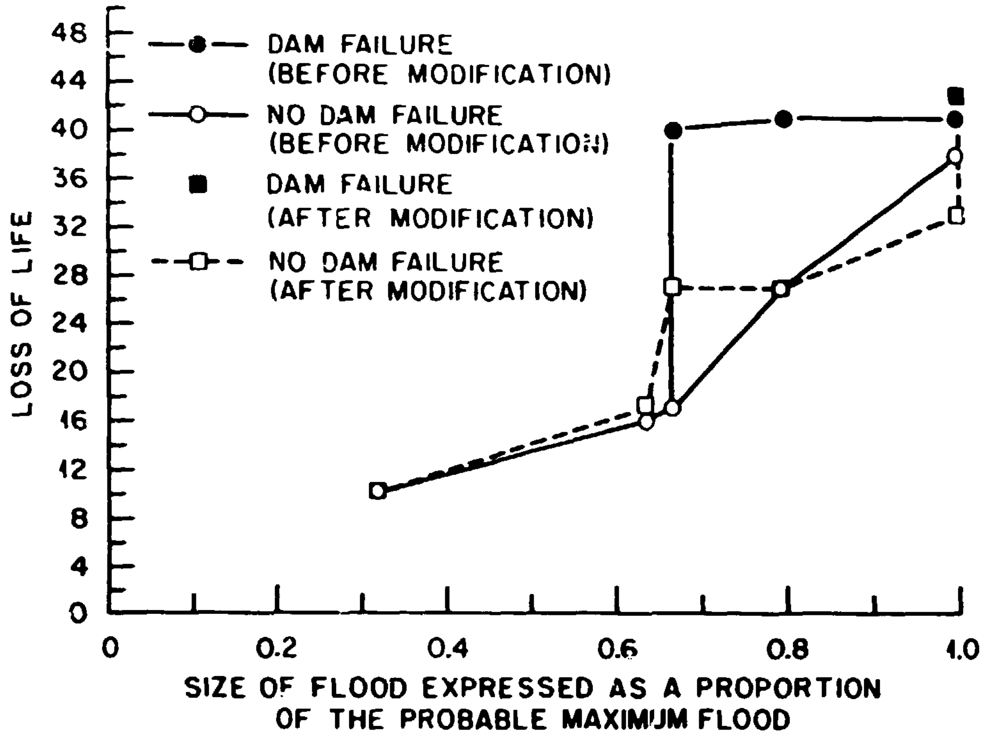

Fig. 3.2. Estimated loss of life in hypothetical dam-related flood events for a New Mexico case study. Note: Modification consists of raising the top of the dam by 3 ft and widening the spillway by 1000 ft.

spillway; with less severe floods, the release of water and expected loss of life are greater than with the existing dam. On the other hand, extremely high loss of life resulting from dam failure would be less likely with the modified dam.

Several flood hazard assessment studies were completed by other division staff. D. M. Evans and D. P. Vogt developed a systematic procedure and supporting software for extracting and compiling economic and population data. J. H. Sorensen and D. M. Neal developed a protocol to assess the effectiveness of emergency and evacuation warning plans in local areas. F. Southworth and S. M. Chin used a traffic evacuation simulation model and developed microcomputer graphics software to estimate the size of the threatened population by comparing network clearance times with flood travel times.

The second focus of the group's activities was energy conservation and the demand for electricity. A study done by T. M. Dinan for DOE's Office of Building and Community Systems (OBCS) increased the understanding of conservation retrofit decisions in the commercial sector. The following five-step plan was recommended for improving the effectiveness of policies designed to promote conservation in the commercial sector:

1. Segment the commercial sector, particularly by ownership type (such as investor-owned or owner-occupant) and by firm size.
2. Identify the barriers and incentives associated with each market segment.
3. Design policies that are targeted at particular market segments.

4. Link the targeted market segments with appropriate technologies (a method for accomplishing this linking process was suggested).
5. Use a flexible approach in directing information at organizations.

A study by Trumble and E. Hirst for the Bonneville Power Administration (BPA) applied econometric theory in model specification and diagnostic testing to data from the BPA Residential Weatherization Program (RWP). Data on monthly electricity bills, daily temperatures, household demographics, structure characteristics, heating fuels, and recent conservation actions were used to estimate econometric models of household electricity demand. Lagrange multiplier tests indicated two problems with ordinary least-squares estimates of the demand functions: the error variance was correlated with household characteristics, and the within-household covariance was nonzero. A maximum likelihood estimator was formulated that addressed both problems. It provided reliable estimates of the electricity savings directly attributed to the BPA program. Estimated average savings ranged from 3380 to 3670 kWh/year for homes that used electricity as the primary heating fuel (see Table 3.4).

A follow-up study by Trumble and Hirst on the Hood River Project for BPA evaluated the residential electricity savings resulting from conservation retrofit measures. The analysis used a two-stage procedure using the PRISM approach and pooled cross-section/time-series econometric models. The results indicated that savings for single-family dwellings averaged 2900 kWh/year, a figure considerably lower than previous estimates of up to 8000 kWh/year obtained from energy audits. Savings for all dwellings (not just single-family dwellings) averaged 2600 kWh/year. The savings from the Hood River study were less than those in the RWP because the Hood River study was done following the RWP, after which real electricity prices had increased and households had already decreased their electricity use in response to the higher prices.

Other studies of energy conservation, headed by Dinan, were (1) a case study of the methodology used by BPA to consider the role of price-induced conservation in meeting future electricity needs (see Sect. 3.2.4); (2) an examination (for BPA) of the factors affecting indoor temperature settings, with emphasis on determining whether households "take back" energy savings by choosing higher winter temperature levels after a retrofit; and (3) a survey (for ORNL) of the conservation investment decision process, using replacement gas furnaces as a case study.

The third focus of the group's activities was the study of the energy supply. For the Department of the Navy, Das and Lee completed a forecast of the availability of jet and distillate fuels under various crude oil supply disruption scenarios (refer to Sect. 7.2.3). Another study, performed by Trumble and D. J. Bjornstad for AID, indicated that oil price increases have played a

Table 3.4. Comparison of estimated weatherization program savings for homes that use electricity as the primary heating fuel

Econometric model	Parameter estimate (kWh/year)	Standard error (kWh/year)
Ordinary least squares	3590	420
Variance	3380	410
Fixed effects	3670	220
Random effects	3670	190
Joint model	3570	130

prominent role in debt creation in developing African countries, though perhaps a lesser role than some had suggested (see Sect. 3.2.2). Lee and Das continued the group's support of EIA's uranium industry viability study by compiling and managing data on uranium supply and demand and the financial status of the industry.

Trumble and Bjornstad examined electrical transmission expenditures and updated the relevant portions of EIA computer models. The project built a comprehensive data base and estimated econometric models with pooled cross-section/time-series data. Separate equations for capital and other expenditures were developed for both transmission and distribution, as well as for other summary measures.

The fourth area of the group's activities was studies of the distribution and management of materials and manpower. A study by Das for the Department of the Navy involved an economic analysis of several competing alternatives for an automated information system to improve manpower management activities (see Sect. 6.1.4). In another study of materials and manpower management, Das developed recommendations for an improved material delivery system at ORNL by consolidating the Plant and Equipment Expediter Group with the Materials Department. The new delivery routes and daily schedules were estimated to save $45,000/year.

3.2 TECHNICAL HIGHLIGHTS

3.2.1 Energy and Agriculture in the Haitian Economy: A Computable General Equilibrium Model

D. W. Jones S. Das
M. T. C. Wu S. M. Cohn

As part of the U.S. AID Energy Policy Development and Conservation Project, a computable general equilibrium (CGE) model of the economy of Haiti was constructed to assist the Haitian Ministry of Mines and Energy Resources develop the energy component of the national five-year plan. The model accounts for agricultural activities and energy production and use in particular detail. Ten major production sectors are specified: rice, coffee, sugar cane, sugar refining, general agriculture, fuelwood and charcoal, electricity, manufacturing, transportation, and services. The use of agricultural residues as fuels is modeled in the rice, sugar cane, sugar refining, and general agricultural sectors. In the service sector, both traditional and modern energy uses are modeled with nested energy production functions. A flexible input-output structure is modeled with the use of intermediate inputs in production functions; the intermediate inputs include both domestic products and imports.

Consumption in the economy is modeled with Stone-Geary utility functions, from which the linear expenditure system (LES) of demand equations is derived. Theoretically consistent systems of LES demand equations are constructed for three categories of individual consumers and a government sector. The individual consumer categories are low-, middle-, and high-income groups, distinguished on the basis of their ownership of land and capital. Government income is derived from tariff and domestic tax revenues and from foreign grants.

The economy exports four categories of products—coffee, refined sugar, general agricultural products, and manufactures—and imports six products—petroleum, coal, food, manufactured consumption goods, "raw" materials used in the manufacturing (assembly) sector, and manufactured agricultural inputs (e.g., fertilizers). Equilibrium requires balance of the trade and capital (foreign grants) accounts.

All production functions in the model are flexible functional forms (i.e., ones in which input employment decisions are affected by relative factor prices). The nested energy production function in the service sector is a Constant Elasticity of Substitution form, and all others are Cobb-Douglas forms.

The sums of the sectoral employments of labor, land, and capital are constrained to add up to the quantities of those factors in the Haitian economy in the early 1980s. This constraint requires a more robust solution algorithm than does unconstrained employment but prevents the possibility of generating by default an unrealistically large or small population, land area, or capital stock.

The model contains over 110 endogenous variables, but its dual structure is used to reduce the system to ten equations in nine prices and one quantity, which are then solved numerically. All other endogenous prices and quantities can be derived from the solution values of these ten variables. The parameters of the model are assigned values on the basis of Haitian data, with occasional supplementation by data from similar developing countries or by figures implied by theoretical restrictions on the Haitian data. A variant of Powell's method for solving systems of nonlinear, algebraic equations is used to solve the ten-equation system. The entire solution procedure involves a series of subroutines that operate on the IBM/AT with a math coprocessor chip, solving quite rapidly; the same subroutines can be used on the IBM PC or IBM/XT but at slower speeds.

The two principal limitations of the model are its degree of aggregation—only ten production sectors—and the fact that it is a static, long-run equilibrium model that does not include savings and investments. However, these limitations, particularly the latter one, are less restrictive than they may first appear. Economic growth and technological change can be simulated by sequentially incrementing the exogenous capital stock and labor force and interpreting part of the consumption of manufactured goods as real savings matching the investment represented by the capital stock increment. Tariff and domestic tax policies can be studied by changing tariff and tax rate parameters; government spending policies can be addressed with parameters in the government demand equations; and deficit spending can be simulated by simultaneously altering the foreign grants variable. Numerous options are available to study the consequences of technological changes in production and energy use.

CGE models are particularly useful for investigating the unintended consequences, as well as the desired effects, of economic policies. However, the models' categorization of products and industrial sectors is more highly aggregated than policy makers will want to use for final policy discussions. A CGE model may point to import tariffs on agricultural inputs as effective policy instruments for the government's purposes, but in deciding which products to tax, and how much, policy makers will want to use other, more narrowly focused analytical tools. The data requirements of CGEs are more lenient than those of econometric models, and CGEs are better equipped to accommodate the structural changes that economic development entails. These structural changes often pose severe stability problems in the estimation and interpretation of coefficients in econometric models.

Figure 3.3 illustrates an execution of the model. It shows the percent changes in six variables following the 25% increase in the petroleum price which Haiti faces. Petroleum imports fall the most, with an elasticity slightly greater than one. Three substitutes for petroleum products—coal,

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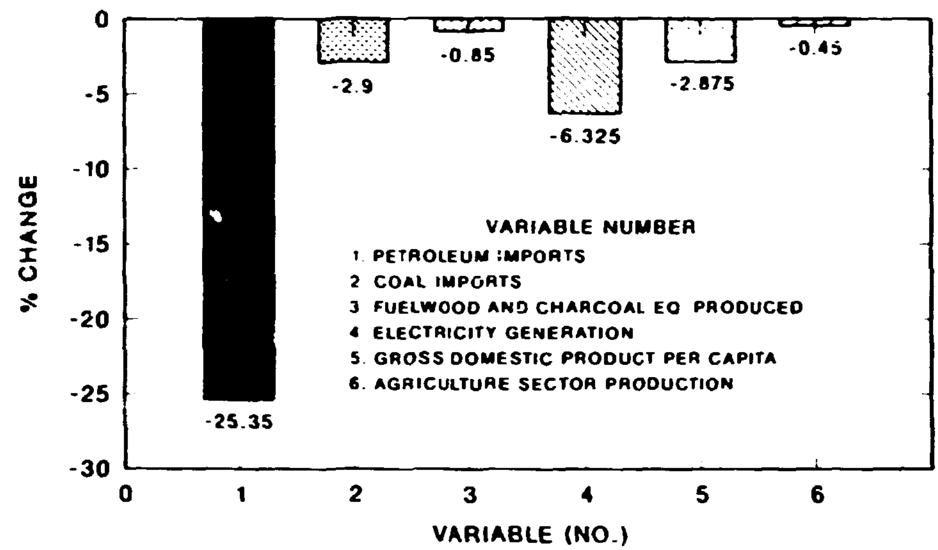

Fig. 3.3. Haiti Model. Scenario: Petroleum price up 25%. Resultant percentage change in quantity variables.

fuelwood/charcoal, and electricity—also fall but by much less. Overall income effects clearly outweigh the substitution effects on consumption of these replacements. Both petroleum and coal are used in electricity generation, and the decrease in electricity generation is greater than that in coal imports. Gross domestic product per capita falls slightly, reflecting the small share of economic activity accounted for by petroleum sales; agricultural production falls the least, partly because of low price and income elasticities of demand and partly because little petroleum is used in agricultural production.

3.2.2 Crude Oil Price Increases and the Foreign Debt of African Nations

D. A. Trumble and D. J. Bjornstad

The formation of debt in developing countries and the influence of debt on the development process are difficult topics with multiple causes and consequences. Nevertheless, there is almost universal agreement that the crude oil price increases dating from 1973 negatively affected the ability of Third World nations to obtain credit to finance productive investments. Instead, foreign-held debt has often been used as a stop-gap measure for financing current purchases of crude oil until adjustments to rapidly changing price regimes can be made.

An attempt has been made to measure the impact that crude oil price increases have had on the buildup of foreign-held debt in a set of AID-supported African countries that do not produce significant amounts of crude oil. To do this, a series of formulas is used to create indirect measurements of this impact. The approach is indirect because it is not possible to observe debt-formation transactions individually. Hence, the following questions arise: What would oil purchases have been if prices had not increased g[illegible]ly? What purchases actually occurred? The difference in projected vs actual purchases is calculated and reported as a ratio of the debt incurred over the study period (1971–83). A number of formulas are required because available data are weak and because proxy variables must be used to carry out the "what if" calculation. We suggest that if a number of alternative calculations yield similar results, confidence in the analysis is increased. Data were obtained from International Monetary Fund and United Nations sources with value figures denominated in current U.S. dollars.

Table 3.5 gives selected results from these calculations. The distinction between refining and nonrefining countries is reflected in the three groups of countries presented. For refining countries, data were not available in a single format. Refining countries import crude oil and usually a range of processed petroleum products. The calculations are not strictly comparable because somewhat different formulas were used for each group to take into account the peculiarities of the group.

Table 3.5. Crude oil cost increase impacts as a percent of debt accumulation, 1971–83

Country	Estimators[a]		
	1	2	3
Nonrefining countries			
Rwanda	62		87
Burundi	35		46
Burkina Faso	22	35	61
Malawi	22	29	49
Gambia	27	29	49
Mauritania	15	11	21
Refining countries (Group A)[b]			
Zambia	29	33	35
Ivory Coast	32	30	33
Morocco	53	49	54
Kenya	51	51	56
Senegal	63	62	68
Refining countries (Group B)[b]			
Tanzania	78	74	82
Sierra Leone	92	75	82
Sudan	28	23	25
Togo	21	24	26

[a]Estimators are not strictly comparable between country groupings. Estimator 1 is energy cost increases measured by recorded costs; estimator 2 is energy cost increases measured by average cost by country groups; and estimator 3 is energy cost increases measured by Saudi crude price increases.

[b]The International Monetary Fund data base used in this analysis provides import information for either crude oil value or total petroleum product value, but not both. For Group A refining countries, crude oil imports are used in the calculations; for Group B, petroleum product imports are used.

The results indicate that crude oil price increases have caused the charges for imported crude oil to increase at a significant fraction of debt accumulation. In a rough sense, without the price increases, debt formation could be reduced by the fractions shown. A rather close correspondence between results is obtained by the various formulas. Column 1 measures the increase in energy costs according to actual purchases. Column 2 measures the increase in energy costs using average price increases for each respective group. Column 3 uses the Saudi Arabian crude oil price as a proxy for price increases. The latter measure tends to be higher than the others, suggesting that effective price impacts were less than spot market price increases. This occurs for a number of reasons, including the impact of long-term sales agreements, discounts, and freight and insurance charges. It also partially masks the effects of changes in world oil trade that have led to a higher fraction of crude oil being traded on spot markets.

This latter fact suggests that recent reductions in spot market prices may be passed along to consumers more rapidly than past oil price increases and that relief could occur more quickly. Conversely, future price increases may be felt more quickly than past ones, suggesting that costs of adjustment to changing price regimes may not abate.

3.2.3 The Economic Feasibility of Recycling Plastic Wastes

T. R. Curlee

The objective of this work has been to assess the economic and institutional feasibility of recycling plastic wastes. Work during the past year focused on (1) an overview of the technological issues related to plastics recycling, including environmental impacts of recycling and disposal; (2) a conceptual overview of the economic and institutional factors that impact the public and private sectors' decisions about recycling plastics; (3) projections of the quantities, qualities, and applicabilities of different types of plastic wastes in particular recycling operations during the next decade; (4) a review of the costs and potential revenues associated with existing and developmental technologies to recycle and dispose of plastic wastes; and (5) a detailed assessment of the feasibility of recycling plastics in three market areas—polyethylene terephthalate beverage bottles, electrical and electronic goods, and automobile shredder residue.

This work has culminated in a recently published book entitled *The Economic Feasibility of Recycling: A Case Study of Plastic Wastes.*[5] The following presents a brief discussion of some of the book's more substantive issues. The discussion of technological issues is focused in three areas: (1) the various types of plastics and how the characteristics of different resins impact their recyclability; (2) the different types or groups of technologies that can be used to dispose of or recycle plastic wastes and some specific examples of technologies within each technology group; and (3) the environmental impacts of disposing of or recycling plastic wastes by using the various available technologies.

A major, if not the major, technical problem in recycling plastic wastes is the diversity of the physical and chemical characteristics of the numerous resins that are called plastics. The recycling of plastic wastes is further complicated by current capabilities to separate plastics from other waste materials. Separating a plastic that has entered the municipal waste stream from other wastes is technically very difficult and not economically viable. Therefore, the ability to collect and process plastic waste before it enters the municipal waste stream is a major constraint to recycling the waste, at least in a relatively uncontaminated form. The various ways in which plastics can be recycled create other technical complications. Numerous recycling technologies are available, and others are being developed. These fall into four categories: primary, secondary, tertiary, and quaternary recycling.

Briefly, primary recycling means the conversion of the waste into products with physical and chemical properties equivalent to the original product or resin. Secondary recycling refers to the production of goods or materials with physical and chemical properties that are inferior to the original good or resin. Most of the secondary processes involve the reheating and reforming of thermoplastics into new forms or alternatively, the use of the waste plastics as filler materials with virgin resins. Tertiary recycling refers to the production of basic chemicals and fuels by processes such as pyrolysis. Quaternary recycling refers to incineration with heat recovery. Primary and secondary processes require relatively clean waste, while tertiary and quaternary processes can accommodate plastics within or segregated from the municipal waste stream.

Yet another important technological issue, especially from a social perspective, is the environmental damage that may result from the incineration or landfill of plastic waste (the usual disposal methods), as well as the potential environmental damage that may be caused by different forms of recycling. There is, however, no general agreement about the environmental impacts of disposing of plastics. What is clear is that the recycling of plastic wastes does not completely eliminate the potential environmental problems they pose.

The general discussion of economic and institutional issues is presented from two perspectives—that of the private firms involved in the production, disposal, and recycling of plastic wastes and that of the public sector, which must, through legislation and regulations, voice an opinion on the issue. The private firm that produces plastic wastes has an obvious incentive to recycle when the direct costs of recycling are less than those of disposal. The picture is somewhat clouded, however, by potential institutional problems. The book[5] reviews numerous institutional incentives and barriers relevant to different segments of the private sector. From society's perspective, two sets of economic and institutional issues arise. First, should the public sector encourage private firms to recycle plastics rather than dispose of them by incineration or landfill? Second, to what extent should the public sector make efforts to recycle postconsumer plastics that appear in the municipal waste stream? The book[5] suggests several reasons for government involvement but also warns of the potential detrimental effects of poorly designed programs.

The production of plastic wastes in future years is one of the principal uncertainties facing private and public decision makers. The book[5] contains estimates and projections of manufacturing and postconsumer plastic wastes for the years 1984, 1990, and 1995. In addition, it discusses recent trends in the use of resins by major market categories. Projections of total resin use in several U.S. markets are given through the year 1995. The waste projections are disaggregated according to several major thermoplastic and thermosetting resin types. Projections show that manufacturing nuisance plastics in the United States will increase in quantity from the estimated 1.3 billion kg in 1984 to about 1.8 billion kg in 1995 (see Fig. 3.4). About 82% of those wastes over this time frame are projected to be thermoplastics (see Fig. 3.5). Fabrication is the largest single waste-producing manufacturing step (about 32% of the total). Manufacturing nuisance plastics refer only to manufacturing waste that is currently disposed of by incineration or landfill. A large percentage of manufacturing plastic waste has historically been recycled in plant through primary or secondary processes. Nuisance plastics are either too contaminated for such processes or are not recyclable because of their cross-linking molecular structures, which in some cases prevent their remelting and reforming.

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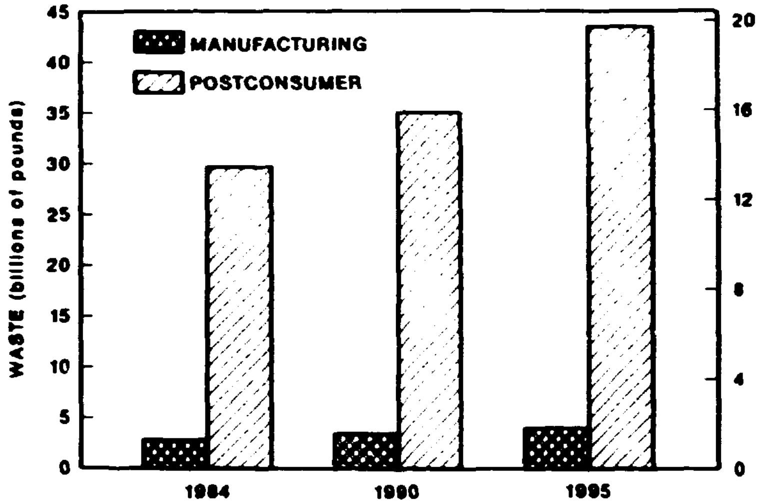

Fig. 3.4. Total plastic waste: 1984, 1990, 1995.

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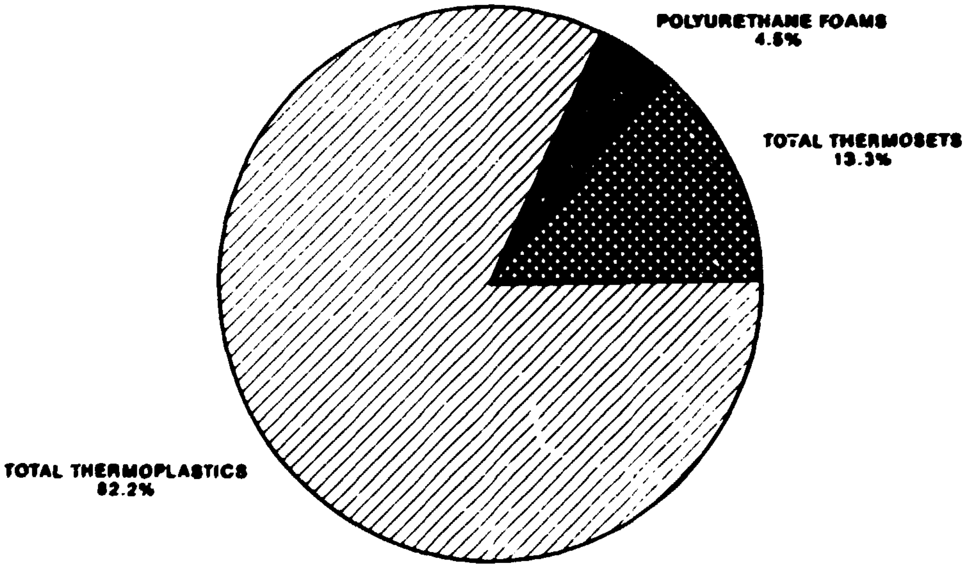

Fig. 3.5. Manufacturing nuisance waste estimates (percentage by plastic type).

Postconsumer waste estimates and projections are presented for 9 major market categories and for 15 major resin types within each category. Total postconsumer plastic wastes are projected to increase from the estimated 13.4 billion kg in 1984 to 19.7 billion kg in 1995 (Fig. 3.4). Figures 3.6 and 3.7 give estimates of postconsumer wastes for the year 1984 by percentage and quantity, respectively. Figures 3.8 and 3.9 give the same information for the year 1995. Thermoplastics are estimated to have comprised about 87% of all postconsumer wastes in 1984 and are projected to increase slightly to about 88% in 1995. Packaging is by far the largest single contributor to postconsumer plastic wastes, in excess of 42% of the total for all years. Plastic waste from the building and construction sector is projected to grow the fastest of all product categories. Various postconsumer product categories are combined with industrial nuisance plastics to suggest the types, quantities, and qualities of plastic wastes that will be difficult and relatively easy to divert from the municipal waste stream. Approximately 25% of all plastic wastes produced during the next decade will be candidates for recycling outside of the municipal waste stream. The remaining 75% will be limited to tertiary and quaternary recycling with other wastes in the municipal waste stream.

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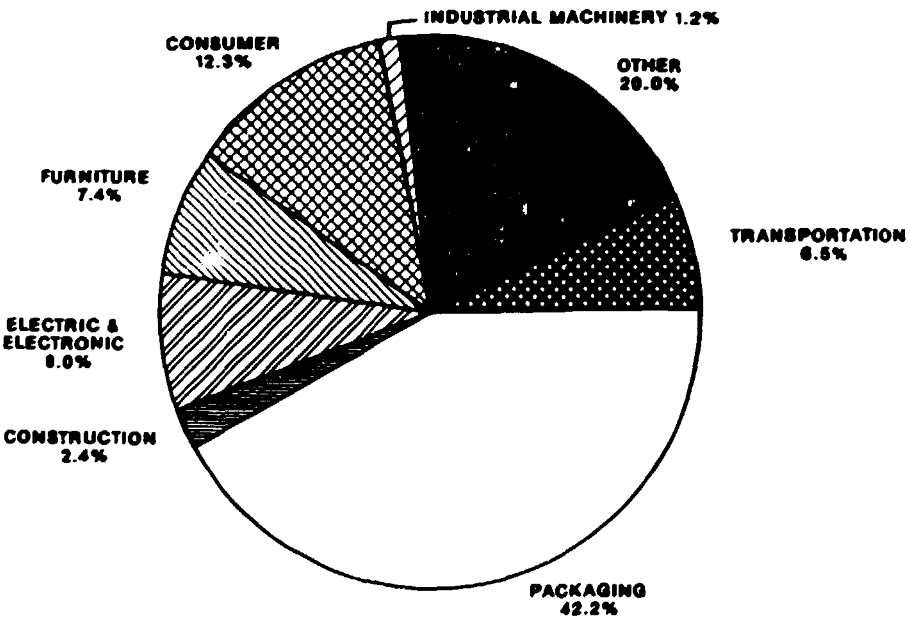

Fig. 3.6. 1984 postconsumer waste estimates (percentage by product category).

The book[5] also focuses on published estimates of the direct expected costs and revenues associated with particular technologies. Disposal alternatives include landfill as a function of population size and several different types of incineration. Numerous secondary, tertiary, and quaternary recycling technologies are considered. While the availability of data is currently quite limited and the quality of some data is questionable, the data at hand indicate that, in many cases, plastics recycling is superior to disposal on a direct expected-cost basis. Further, the numbers suggest that tertiary and quaternary recycling processes, which can accommodate relatively contaminated plastic wastes, are competitive with many of the more restrictive secondary processes.

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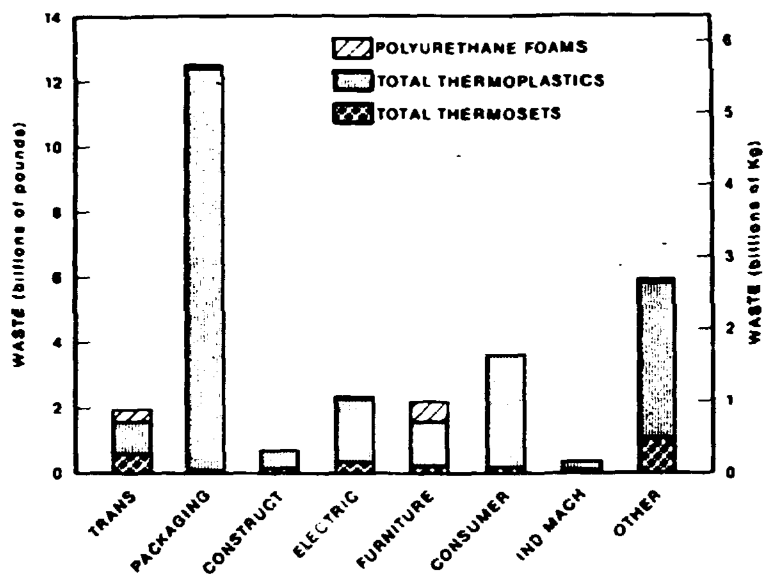

Fig. 3.7. 1984 postconsumer waste estimates.

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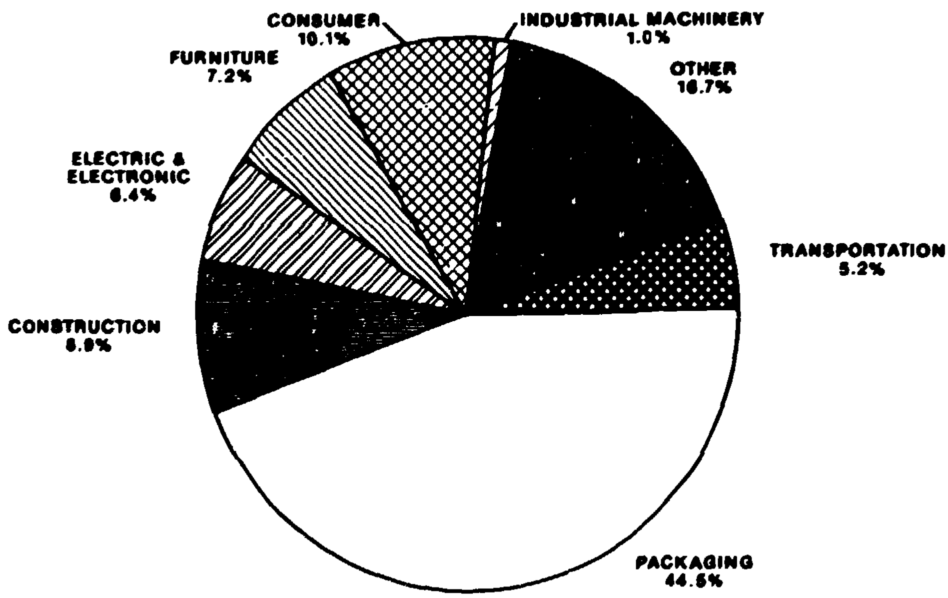

Fig. 3.8. 1995 postconsumer waste projections (percentage by product category).

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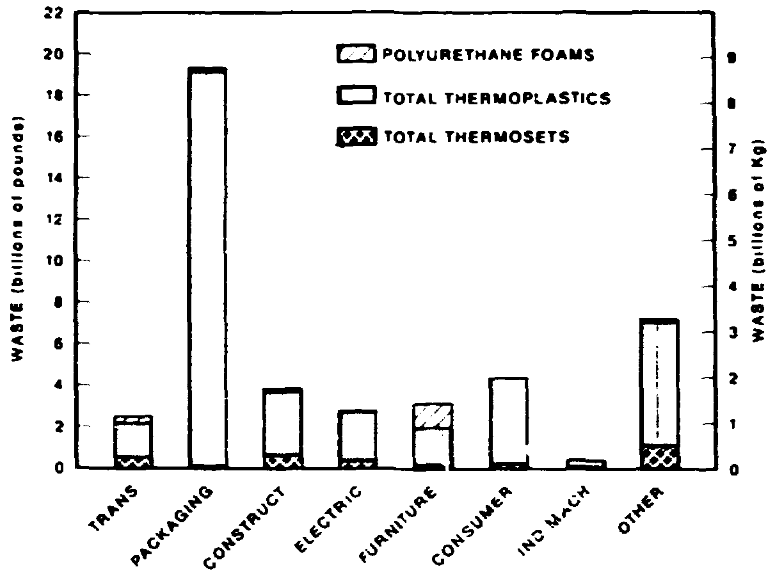

Fig. 3.9. 1995 postconsumer waste projections.

The overriding conclusion of the book[5] is that, given the current economic and institutional incentives and barriers and the current state of recycling technologies, the recycling of plastics as relatively uncontaminated waste can be expected to grow in future years in certain narrowly defined product categories. However, the recycling of plastics to the extent occurring now in the major metals (e.g., steel, aluminum, and copper) is not expected. Fundamental economic, institutional, and technological constraints will limit recycling outside of the municipal waste streams to a small percentage of the total plastic wastes projected to be produced during the next decade.

Recycling within the municipal waste stream is, however, currently on the rise. This trend is expected to continue as environmental restrictions elevate the cost of landfill and thus make the tertiary and quaternary recycling of municipal waste—inclusive of plastics—an attractive economic alternative. These trends will be particularly pronounced in areas with large populations.

3.2.4 Incorporating Price-Induced Conservation into the Power Planning Process

T. M. Dinan

A recent trend in the utility industry has been toward integrating "conservation energy" resources into the traditional power-supply planning framework. This trend represents a movement toward a more efficient allocation of resources; however, accomplishment of this objective requires that the level of price-induced conservation be measured consistently on both the demand and supply sides of the planning process. A case study of the methodology used by BPA in considering the role that price-induced conservation may play in meeting future electricity needs in the BPA region revealed potential sources of inconsistencies that must be guarded against when incorporating conservation in the power planning process.

BPA is responsible for planning how to meet the electricity requirements of its region at a minimal cost. As part of this effort, electricity demand is forecast for the region over a 20-year horizon. The most efficient mix of resources that may be used to meet the demand forecast is determined by BPA's Office of Conservation using BPA's Least-Cost Mix Model (LCMM). BPA considers conservation as a resource that may be used to meet future energy demand and thus estimates conservation supply curves, which are sent to the LCMM. However, in estimating the conservation supply curve, care must be taken to exclude the amount of conservation that will be "price induced" over the planning horizon. This exclusion is necessary because price-induced conservation is accounted for in the forecast of future electricity demand. Failure to exclude price-induced conservation from the supply curves would result in a double-counting of the resource potential of price-induced conservation (i.e., price-induced conservation would be counted both as a decrease in future demand and as a supply for meeting future demand). Conversely, if conservation potential is excluded from the supply curve (under the assumption that it is price induced) but is not included in the load forecast, then the total potential of conservation is under-counted. To avoid double-counting or under-counting conservation potential, BPA's Office of Conservation estimates the level of price-induced conservation and then subtracts this from the conservation supply curve. This method will eliminate the double-counting or under-counting potential only if the level of price-induced conservation that is subtracted from the supply curve is consistent with the level of price-induced conservation in the load forecast.

Three inconsistencies were found between the estimates of price-induced conservation produced by the Office of Conservation and those implicit in the load forecasting models of the Division of Power Forecasting. First, the concept of price-induced conservation differs between the Office of Conservation and the Division of Power Forecasting. In the forecasting models, electricity price changes impact equipment efficiency levels, fuel choice, and utilization intensity. In addition, changes in household income levels will affect these choices. However, the Office of Conservation's estimate of price-induced conservation includes only changes in electricity demand resulting from price-induced changes in equipment efficiency. Second, even after adjusting for definitional differences, the technological possibilities underlying the two estimates are different. Third, the estimate of price-induced conservation produced by the Office of Conservation and the level of price-induced conservation included in the electricity demand forecast are based on different relationships between the electricity price forecast and the level of price-induced conservation. For example, in the load forecast, the level of price-induced conservation is directly related to the electricity price forecast, whereas the Office of Conservation's estimates of price-induced conservation for the commercial sector and for some divisions of the residential sector are independent of future electricity prices (20% of all technically feasible efficiency improvements are assumed to be price induced). These inconsistencies may result in large discrepancies between the two estimates of price-induced conservation. Table 3.6 shows the magnitude of these discrepancies in 1985.

These discrepancies result in an under-counting of conservation potential in both the residential sector and in the commercial sector served by publicly owned utilities. The reason was that the amount of conservation that is subtracted from the supply curves (the Office of Conservation's estimate of price-induced conservation) was greater than the amount in the demand forecast (the Division of Power Forecasting's estimate). The discrepancies indicate a double-counting of

Table 3.6. Comparison of the BPA Office of Conservation with the BPA Division of Power Forecasting Results (1985 estimates of the level of price-induced conservation that will occur in the year 2005[a])

Source of savings	Office of Conservation estimate (MW)	Division of Power Forecasting estimate (MW)
	Residential Sector	
Thermal integrity improvements	0	4.5 (combined)
Space heating equipment efficiency improvements	0	
Efficiency improvements in appliances	118	2.4
Efficiency improvements in water heating	131	4.8
Total	249	11.7
	Commercial Sector	
Public utilities rate pool	49	−11[b]
IOU rate pool	54	99
Total	103	88

[a]To be consistent with the concept of price-induced conservation that is used by the Office of Conservation in estimating their supply curves, price-induced conservation is defined to be the decrease in electricity use resulting from price-induced changes in equipment or structural efficiency. Changes in electricity use caused by changes in usage intensity and fuel switching are not included in the estimate of price-induced conservation presented here.

[b]A negative number indicates a decrease in efficiency.

conservation potential for the investor-owned-utility (IOU) rate pool of the commercial sector because the amount of conservation subtracted from the supply curves is less than the amount in the demand forecast.

The BPA findings highlight the need to guard against inconsistencies that may lead to a double-counting or under-counting of the resource potential of conservation. Inconsistencies in demand- and supply-side estimates of price-induced conservation may be avoided by using a consistent definition of what constitutes "price-induced" conservation, agreeing on a consistent set of conservation technologies that create price-induced conservation potential, and using a consistent methodology to estimate the actual level of price-induced conservation. In the case of BPA, it was recommended that the actual estimate of price-induced conservation be obtained from the load forecast and then subtracted from the supply curve. This methodology would eliminate the possibility of double-counting or under-counting the estimates of price-induced conservation potential.

3.2.5 Herbaceous Energy Crops as an Alcohol Feedstock

A. F. Turhollow J. H. Cushman* J. W. Johnston*

The Herbaceous Energy Crops Program contributed a section on the production of lignocellulosic crops as part of a fuel alcohol technical and economic evaluation study coordinated by the Solar Energy Research Institute. Species representative of regions considered to have a good potential for growing herbaceous energy crops in the eastern United States were selected; they include napier grass (*Pennisetum purpureum*), Bermuda grass (*Cynodon dactylon*), sericea lespedeza (*Lespedeza cuneata*), switchgrass (*Panicum virgatum*), reed canary grass (*Phalaris arundinacea*), tall fescue (*Festuca arundinacea*), and sweet sorghum (*Sorghum bicolor*) (see Fig. 3.10). Sweet sorghum is an annual species, and the others are perennials. Reed canary grass and tall fescue are cool-season species, and the rest are warm-season species. Sericea lespedeza is the only legume.

Based on a number of assumptions, the most important of which are listed in Table 3.7, cost estimates were made for each species in the indicated region. Primarily because of the selection of, and breeding improvements in, crops grown for energy, the hypothesized yields increased between 1985 and 2000 (see Table 3.8). These crops were selected and bred primarily for livestock feed. The regional cost differences are more important than the cost of a particular species. In-field production cost estimates of what could be achieved in 1985 and what is possible in 2000 are also presented in Table 3.8. Costs decrease mainly because of increased yields and optimized agronomic management practices.

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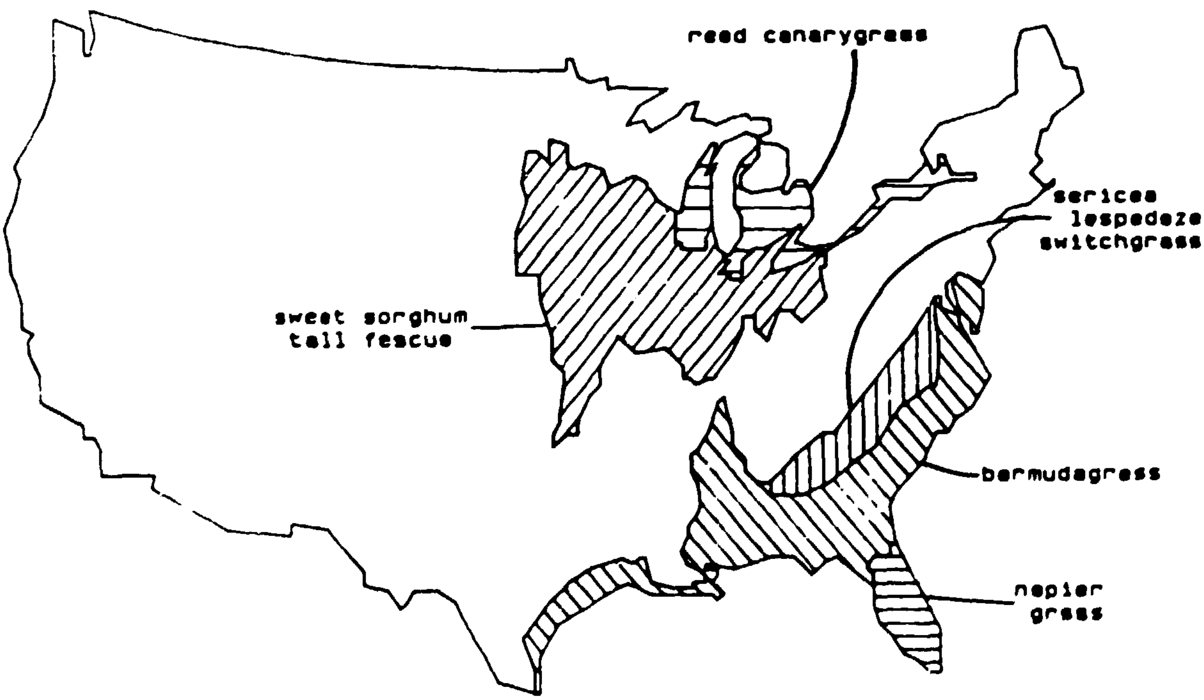

Fig. 3.10. Representative regions for lignocellulosic crops used in fuel alcohol study.

*Environmental Sciences Division.

Table 3.7. Important assumptions used in cost estimates for lignocellulosic energy crops

81 ha of 162-ha farm in lignocellulosic energy crops

Harvest twice a year using large-round-bale haying system, except for napier grass, which is harvested once a year, and sweet sorghum, which is harvested once a year using a silage system

Fertilizer applied replaces nutrients removed in harvest

- In 1985, harvested crop assumed to be 1.5% nitrogen, 0.3% phosphorus, 1.5% potassium
- In 2000, harvested crop assumed to be 1.0% nitrogen, 0.2% phosphorus, 1.0% potassium
- Sericea lespedeza requires no nitrogen

Fertilizer costs are 53¢/kg nitrogen, 49¢/kg P_2O_5, 19¢/kg K_2O

Establishment costs are $370/ha for perennial crops; no harvest in established year

Storage loss of 14%

Table 3.8. Estimated in-field production costs for lignocellulosic energy crops

Region (crop)	1985		2000	
	Hypothesized yield (Mg/ha)	Cost[a] ($/Mg)	Hypothesized yield (Mg/ha)	Cost[a] ($/Mg)
Subtropics (napier grass)	18.0	42.10	27.0	29.50
Southeast (Bermuda grass)	18.0	40.60	27.0	28.50
Piedmont (switch grass)	9.0	61.50	13.5	41.40
Piedmont (sericea lespedeza)	9.0	51.30	13.5	34.60
Lake states (reed canary grass)	12.0	49.60	18.0	34.20
Midwest (tall fescue)	15.0	49.30	22.5	34.40
Midwest (sweet sorghum)	18.0	58.20	27.0	38.80

[a]Includes no transportation cost and allows for 14% storage loss.

Transportation costs from the field to the alcohol conversion facility are not insignificant. It was assumed that only a 30-d supply of feedstock is maintained at the alcohol plant, with feedstock being stored along a roadside near the field where the feedstock is grown. Transportation costs are a function of the distance transported, which depends on the alcohol plant size, the crop yield, and the density of feedstock production. A cost function of $1.58/Mg plus $0.0975/Mg-km one way was used to calculate these transportation costs. Two plant sizes, 95 million L/year and 568 million L/year, and a feedstock requirement of 6 kg/L in 1985 were assumed. For the 95-million-L/year plant, transportation costs ranged from $1.70 to $7.82/Mg; for the 568-million-L/year plant, costs ranged from $4.09 to $16.64/Mg.

3.2.6 Automotive Fuel Economy Improvements and Consumers' Surplus

D. L. Greene
J. T. Liu*

Since 1974, the average fuel efficiency of new automobiles sold in the United States has approximately doubled, from 16.8 liters per 100 kilometers (L/100 km) to 8.4 L/100 km.[21] The cumulative, direct fuel cost savings of this improvement have been estimated at approximately $90 billion (1984 dollars) from 1975 through 1984,[13] so that the value of direct fuel savings to date must be in excess of $100 billion.

The direct monetary costs of these fuel savings to automobile buyers are more difficult to estimate because manufacturers' research, development, and retooling investments generally have multiple objectives. Nonetheless, costs of cumulative fuel economy improvements from 1978 to 1985 have been estimated in the range of $200–$400 (1981 dollars) per car.[13] This range is generally consistent with adjustments to the consumer price index for automobiles made for fuel economy and other improvements over this period.[22] Assuming the average cost for the 10-year period was about $200 per car and assuming an average of 10 million automobiles sold per year, the total direct cost of fuel economy improvements amounts to approximately $20 billion ($23 billion in 1984 dollars).

Most difficult to appraise is the change in consumer satisfaction that may have occurred as other vehicle characteristics were altered to reduce L/100 km. Quantitative estimates can be derived, however, via the economic theory of consumers' surplus (the total dollar value that the consumer derives by consuming a good minus its total cost). The essence of the approach is to attach a dollar value to a marginal change in the quantity of some attribute directly or indirectly related to fuel economy (e.g., interior space) and, using actual statistics on makes and models sold between 1978 and 1985, compute an estimate of the value of all fuel-efficiency-related design changes.

Three difficult problems had to be resolved before consumers' surplus could be computed:

1. identifying the relevant attributes and their marginal values,
2. specifying a functional form for the utility function, and
3. representing the demand for attributes, including the existing pattern of vehicle choices and changes caused by changes in both observed and unobserved attributes.

Relevant attributes must be important to consumers and must have a direct or indirect causal relationship to fuel economy. For our study, we selected weight, performance (measured as the engine size-to-weight ratio), interior volume, and annual fuel cost. Attribute values were selected based on judgment and on a review of the literature. We specified linear utility functions, which will be a reasonable approximation to any utility function for small changes in attributes. Two variants of the multinomial logit model of consumer choice, a type of random utility model, were used to represent the demand for vehicle attributes.

Random utility models address the decision to purchase one discrete item from a set of potential choices, all of which satisfy essentially the same need. The consumer is presumed to select the option that offers him the greatest utility or satisfaction. The utility (U) of an alternative is

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assumed to be a stochastic function of the attributes (x_i, $i=1, N$) of the alternative (and possibly of the consumer) and a set of taste parameters (a_i, $i=1, N$) that describe the weight attached to each attribute in determining utility,

$$U = U(x_i, a_i) \ . \tag{1}$$

The simplest stochastic specification of U is to assume that it consists of a common component which is the same for all consumers and depends on x and a, plus an additive random term (e_{tj}) for each individual, t, and alternative, j:

$$U_{tj} = \Sigma a_i x_{ij} + e_{tj} \ . \tag{2}$$

If the e_{tj}'s have an extreme value distribution, then the probability of consumer t choosing alternative j is given by the multinomial logit model (MNL):[23]

$$P_{tj} = \frac{\exp(U_{tj})}{\sum_k \exp(U_{tk})} \ . \tag{3}$$

The expressions exp{ } and ln{ } in Eqs. 3, 4, and 5 indicate exponentiation and natural logarithms, respectively. If the parameters a_i in Eq. 2 are also assumed to be randomly distributed over the population of consumers according to some distribution (e_{tj}'s still distributed extreme value), then the Hedonic Demand Model (HDM) results.[24] The HDM is considerably more complex: evaluating the probability of choice of j requires integrating over the probability distribution of all N attribute weights. This involves a multiple integral with order equal to the number of attributes.

It is intuitively clear that when either the number of choices available or the attributes of choices change, the levels of satisfaction that can be reached by consumers will also change. For the MNL model, it has been shown[25,26] that the precise change in consumers' surplus is

$$\$CS = \sum_t (1/a_0)[\ln\{(\sum_{j:M2} \exp\{U_{tj}(a, x')\})/\sum_{k:M1} \exp\{U_{tk}(a, x)\}\}] \ . \tag{4}$$

For the HDM, the corresponding consumers' surplus change is given by[27]

$$\$CS = T\int \ldots \int (1/a_0) \ln\{\ldots\ldots\} f(a|m,\Sigma)da \ , \tag{5}$$

where $M1$ and $M2$ represent the initial and new choice sets, with x' being the new characteristics of choice set $M2$. The expression ln{...} is shorthand for the same log term in Eq. 4. The probability distribution of the a_i's is $f(a \mid m, \Sigma)$, with m representing the vector of means of the a_i's and Σ representing their variance-covariance matrix. Finally, a_0 is the weight of the price of the alternatives (the marginal utility of income), so that ($1/a_0$) translates the utility measure into dollars. Equation 4 can be computed directly, while Eq. 5 can be computed by Monte Carlo integration methods.[28]

In our calculations, we assume that buyers compare this year's autos with last year's makes and models at this year's fuel prices. Our calculations answer the question, "Would I have been happier with last year's models at this year's fuel prices?" The difference in satisfaction is capitalized in the current year, assuming that fuel prices remain at the current year's level. To the extent that prices ris or fall thereafter, the actual consumers' surplus change will be larger or smaller.

Two sets of calculations are performed, one weighted by vehicle market shares, the other not. If the results are nearly the same for both calculations, it is an indication that vehicle characteristics left out of the utility functions would not alter the results significantly. An initial set of attribute values was derived by choosing the median attribute values from ten published studies. This set (shown in Table 3.9) exhibits very high values, in our opinion, for weight and performance. A marginal value of \$2.45/kg implies that the typical consumer would be willing to pay over \$1000 to add 90.91 kg to his car, all else (including interior space, performance, fuel economy, etc.) being equal. A more reasonable value of \$0.45/kg is used in MNL case 2.

The value of performance also appears to us to be high. A value of \$547/(0.0745 $cm^3 \cdot kg$) implies that the average car buyer would pay over \$1000 to reduce his car's 0–96.5 km/h acceleration time from 11.5 to 10 s. In case 3, we have assumed that the average buyer would pay only \$250 for a 0.0745-cm^3/kg increase in the ratio of engine size to weight.

Each attribute weight of the HDM requires two parameters: the μ and σ of its lognormal distribution. These are derived by using the literature estimates to construct an approximation to a 95% confidence interval (the 2.5 and 97.5 percentiles) for the distribution of the parameter. The results are provided in Table 3.10.

The consumers' surplus estimates presented below are conditional on these consensus estimates. The MNL consumers' surplus estimates are especially sensitive to the value of weight (see Table 3.11). At a value of \$12/kg, consumers suffer a tremendous surplus loss in 1979. Although succeeding years' cars are seen as improvements over previous years' models, the over \$1000 loss in

Table 3.9. Attribute values for MNL model, cases 1, 2, and 3

Attributes	Coefficient	\$/unit
Case 1		
Price, \$	−0.00056	(1.00)[a]
Op. cost, \$/year	−0.00204	(3.66)
Space, L	0.001582	2.82
Weight, kg	0.006626	11.84
Power, 0.01 cm^3 displacement/kg	4.1108	73.41
Case 2		
Price, \$	−0.00056	(1.00)
Op. cost, \$/year	−0.00204	(3.66)
Space, L	0.001582	2.82
Weight, kg	0.001232	2.20
Power, 0.01 cm^3 displacement/kg	4.1108	73.41
Case 3		
Price, \$	−0.00056	(1.00)
Op. cost, \$/year	−0.00204	(3.66)
Space, L	0.001582	2.82
Weight, kg	0.001232	2.20
Power, 0.01 cm^3 displacement/kg	1.8788	33.55

[a]Parentheses indicate a negative value.

Table 3.10. Attribute value parameters of the Hedonic Demand Model

Attribute	sign	E(β)	$/unit
Price, $	−	−0.00056	−1.00
Operating cost, $/year	−	−0.00198	−3.55
Interior space, L	+	0.00133	2.37
Weight, kg	+	0.00365	6.53
Power, 0.01 cm^3 displacement/kg	+	0.01139	20.34

Table 3.11. Consumers' surplus estimates: MNL, cases 1-3
(Values are in dollars)

	Year							Average
	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	
	Case 1—original attribute weights, year to year							
Weighted	(1171)[a]	(135)	329	184	(98)	23	(312)	(16)
Nonweighted	(1192)	41	336	(42)	146	50	(316)	(140)
	Case 2—$2.2/kg, year to year							
Weighted	16	284	507	212	(10)	(430)	107	98
Nonweighted	283	391	596	176	211	(290)	28	199
	Case 3—$2.2/kg, $250/0.0745 cm^3 displacement/kg, year to year							
Weighted	93	495	527	265	24	(26)	108	212
Nonweighted	348	531	647	246	271	38	21	300
	Cumulative sums of annual effects							
Case 1	(1171)	(1306)	(977)	(793)	(891)	(868)	(1180)	
Case 2	16	300	807	1019	1009	579	685	
Case 3	93	587	1114	1379	1403	1377	1485	

[a]Parentheses indicate a negative value.

1979 is never recovered. The average loss per car per year for the 1978–85 period is about $150 (Table 3.11, case 1).

If we assume that the average consumer is willing to pay only $2.2/kg for additional weight (all else equal) and $250/(0.0745 $cm^3 \cdot kg$), the results change drastically. If we accumulate the surplus changes over the seven-year period, consumers come out way ahead: $100 the first year, $600 the second year, and more than $1000 every year thereafter. In this case, the gain in consumers' surplus is just over $10 billion/year.

The HDM estimates are theoretically more satisfying because they recognize that there is no typical consumer, but rather a distribution of consumers with differing tastes represented by the parameter distributions described above. Because Monte Carlo methods are used to compute surpluses in the HDM, six runs starting from six different random number seeds were carried out. The results yielded consumers' surplus estimates that fall between cases 1 and 3 for the MNL model (see Table 3.12). According to these estimates, consumers experienced surplus losses in 1979 and 1985 but gains in all other years. The losses can be attributed primarily to the decreases in

Table 3.12. Estimated consumers' surplus: HDM estimates
(Values are in dollars)

Run No.	Years								Average	Sum
	1978–79 (No weights)	1978–79	1979–80	1980–81	1981–82	1982–83	1983–84	1984–85		
1	(569.26)[a]	(604.56)	203.34	455.71	155.43	136.16	469.85	(204.82)	87.30	611.11
2	(713.16)	(672.11)	48.59	427.95	114.51	178.89	505.76	(262.33)	48.75	341.26
3	(691.00)	(647.53)	(39.32)	419.93	102.61	182.74	486.04	(259.99)	34.93	244.48
4	158.13	(52.99)	361.77	425.49	198.45	62.10	207.44	20.32	174.65	1222.58
5	(632.33)	(638.86)	172.53	438.46	140.68	150.74	491.32	(230.56)	74.90	524.31
6	(568.14)	(605.79)	182.94	458.48	155.33	134.87	467.31	(204.00)	84.16	589.14
				Summary statistics						
mean	(502.63)	(536.97)	154.98	437.67	144.50	140.92	437.95	(190.23)	84.12	588.81
std. dev.	300.54	217.72	126.00	14.81	31.13	39.91	103.90	96.98	44.65	312.56
std. dev. of means	122.70	88.88	51.44	6.05	12.71	16.29	42.42	39.59	18.23	127.60
cumulative change	(502.63)	(536.97)	(382.00)	55.67	200.17	341.09	779.04	588.81		

[a]Parentheses indicate a negative value.

weight and engine size in 1979 and 1985 and to the decline in fuel prices in 1985, offsetting the benefit of fuel economy improvements. The average change per year is approximately +$85 for a cumulative total of nearly +$600 for the entire period.

If we take $400 per car as an approximate and appropriately round estimate of the cost of fuel economy improvements, and if we take the HDM estimate of consumers' surplus change ($588 apart from direct price increases) for L/100 km improvements to be the most reasonable, then it appears that the costs and benefits to the consumer are roughly equal. (Within the limits of accuracy of this analysis, differences of this size cannot be reliably discerned.) Upon reflection, this result should not be surprising. It was not necessary for vehicle manufacturers to produce only subcompacts to achieve the fuel economy standards as some feared.[27] Manufacturers were far more ingenious than that. By changing vehicle designs to preserve interior volume and by introducing better technology, the manufacturers were able to keep consumers just as happy with their new cars as with their old ones.

Although the mathematics of the techniques we have used are somewhat complex, the approach itself is fundamentally straightforward. It relies on directly measuring the relatively small changes in vehicle attributes from one year to the next. It assumes that whatever preference structure consumers have can be approximated by a linear function for these small changes, and it uses what is essentially a probability-of-choice-weighted sum (integral) of the utility changes to estimate the change in consumers' surplus. Using what we believe to be reasonable ranges of attribute values, we find that the change in consumers' surplus over the 1978–85 period is approximately zero. That is, fuel cost savings from higher MPG approximately compensate for changes in weight, engine size to weight, interior space, and fuel economy as reflected in higher retail prices.

3.3 RESEARCH UTILIZATION

Several outputs by members of the Energy and Technology Economics Group are used as inputs by decision makers. Economic impacts measured through the Economic Resource Impact

Statement project are used by planners in their annual review of Air Force base activities and in special studies, such as those to consider base closings. Work on potential energy savings from advanced materials continues to be an important element in planning for DOE's ECUT program. A number of private sector inquiries have also been received following publication of Curlee's plastics recycling book.[5] Finally, virtually all outputs from the EIA Program are factored into EIA's ongoing activities. For example, work by Hill on electric utility behavior by ownership type was the basis of a presentation by EIA staff to its advisory committee.

The prototype IMEASY system was installed on the FEMA computer system in February 1986. During the remainder of the year, FEMA has exercised the system in a variety of in-house studies, including an assessment of the potential economic losses resulting from an earthquake in the New Madrid Fault centered in Cairo, Missouri. These test exercises have provided feedback and additional concepts for future developments of the IMEASY system. For example, one such extension identified and incorporated in the system as a result of FEMA's use has been the inclusion of the capability to develop an economic characterization for a user-defined multicounty region in a nondisaster setting. Also, during the past year, REE staff members transferred the CGE Model for Haiti and the Economic/Energy Data Query System to the Haitian Ministry of Mines. The transfer involved a site visit and demonstration of the systems. The experience gained by the ministry staff in using the two systems during the site visit was then used by the ORNL staff to develop several modifications to the systems. The REE group's work to develop a nuclear power plant data base and to analyze construction costs was published in two separate reports by EIA.[29,30]

Research papers, reports, and software developed by the Transportation Group have been used by DOE, DOD, DOT, and the private sector. Traditional products, the *Motor Vehicle MPG and Market Shares Report*[19] and the *Transportation Energy Data Book*,[20] continue to receive widespread use, being cited by the Motor Vehicle Manufacturers' Association, the Transportation Research Board, and many other private and public research organizations. These two publications are sent out, only in response to written requests, to nationwide mailing lists of over 250 and 1000, respectively. The ORNL National Highway Network, the most accurate and detailed in existence, was produced for the U.S. Army but has been transferred to DOT for use in data display, analysis, and modeling. Other models, for energy demand modeling, automobile market simulation, and consumers' surplus calculation, developed for DOE, have been transferred to researchers in the United States (e.g., General Motors Research Laboratory) and abroad. The group has distributed beta test versions of its HOV Simulation Model to two planning groups in California and will be following up with a final version based on this experience.

Most Resource Analysis and Planning Group research projects contribute directly to planning, policy, and analysis activities of public agencies. The results of the Dam Safety Risk Analysis project will contribute to the establishment of Base Safety Conditions for Corps of Engineers' dams; some of the methods developed in the project will be incorporated in the Corps' guidelines for dam hazard assessment. Studies on energy conservation and the demand for electricity are used by BPA to better understand retrofit decisions and savings in the commercial and residential sectors and to assist in estimating annual loads. Studies for the Navy have assisted in its long-range energy and technology planning and in selecting appropriate computer systems for improving manpower management activities. Information and analysis developed for EIA projects are in support of EIA's data and information activities, including the Secretary of Energy's Report to Congress on the viability of the uranium industry as required under Public Law 97-415.

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4. Efficiency and Renewables Research Section

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4.1 INTRODUCTION AND SECTION OVERVIEW

The Efficiency and Renewables Research (ERR) Section conducts research to improve the efficiency of energy end-use and delivery technologies. The major research areas within the Section are related to energy use in buildings and the transmission, distribution, and use of electric energy. Additional work areas include chemical heat pumps (CHP) for industrial applications and a growing body of work on energy security and energy conservation issues for various sponsors within the U.S. Department of Defense (DOD).

Buildings research includes building equipment such as heating, ventilating, and air conditioning (HVAC) systems; building envelopes and materials; and retrofit research to identify the best measures to improve the energy efficiency of existing buildings. Research in electric power systems includes high-voltage transmission [both alternating current (AC) and direct current (DC)], biological effects of high-voltage transmission, materials for power systems applications, the energy security implications of electromagnetic pulse, and power system automation and control. Work on industrial energy end-use has been primarily in the development of chemical heat pumps for high-temperature applications, although the Section also has strong expertise in district heating and cogeneration.

The principal sponsors of work within the Section are the U.S. Department of Energy (DOE) Office of Buildings and Community Systems, the Office of Energy Storage and Distribution, the Office of State and Local Assistance Programs, and the Office of Industrial Programs. DOD sponsors include the U.S. Navy David W. Taylor Research and Development Center, the U.S. Air Force Engineering and Services Center, the U.S. Army Facilities Engineering Support Agency, and the Naval Civil Engineering Laboratories. Other sponsors include the Tennessee Valley Authority (TVA), the Electric Power Research Institute (EPRI), and the Gas Research Institute (GRI).

For several of the DOE sponsors, the ERR Section is responsible for program management activities to assist DOE in overall program planning and execution and technology transfer. Programs managed within the Section depend heavily on other research divisions within ORNL and on extensive subcontracting and industrial participation to accomplish its research goals. Of a total budget of over $21 million during FY 1986, 30% went for work within the Section, 26% went to

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other divisions within the Laboratory, and over 44% was subcontracted to the private sector, including manufacturers, research institutions, and universities.

The remainder of this chapter is organized into three parts. Section 4.1 gives a brief summary of the accomplishments during the year in each of the six major programs areas within the Section. Section 4.2 presents technical highlights of several research projects during the last year. Section 4.3 discusses some of the research utilization and technology transfer activities that occurred within the Section this year.

4.1.1 Building Equipment Research Program

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The objective of the Building Equipment Research (BER) program at ORNL, sponsored by the DOE Office of Buildings and Community Systems, is to develop a technology base for improving the energy efficiency and load characteristics of energy conversion equipment. The primary emphasis of the program has been on equipment used for space heating and cooling and for providing refrigeration and water heating in residential and commercial buildings. The research being pursued under the BER program falls under two key activity areas: thermally activated heat pumps (TAHP) and refrigeration systems. The TAHP work is concentrated on three technologies: absorption heat pumps, Stirling engine-driven heat pumps, and internal combustion (IC) engine-driven heat pumps. Activities under the category of refrigeration systems include research that could be applied to either electric or thermally activated heat pumps. Major activity areas include refrigerant mixtures, capacity modulation, and ground-coupled heat pumps.

Research under the BER program is accomplished using both in-house expertise and the efforts of subcontractors. While the majority of in-house work is performed within the Energy Division, several other divisions of ORNL contribute to the BER program, including Engineering Technology, Metals and Ceramics, Computing and Telecommunications, and Analytical Chemistry.

4.1.1.1 Thermally activated heat pumps

The BER program has revived U.S. industry interest in absorption technology. Two major manufacturers of HVAC equipment, Carrier Corporation and the Trane Company, are involved, as

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is Phillips Engineering Company, a small business with many years of technical experience with absorption equipment. Original performance improvement goals in advanced absorption cycle research (set in a 1982 request for proposals) of >30% in heating and >40% in cooling over then state-of-the-art absorption heat pumps have already been exceeded in laboratory breadboard system tests. The work has been focused on developing three different advanced absorption refrigeration cycle concepts selected by Carrier, Trane, and Phillips based on independent Phase I analytical projects. Trane and Carrier are currently working on Phase II, which involves building a laboratory breadboard system of their selected cycle and proof-testing it. The Phillips Engineering breadboard system was the first advanced cycle to operate, and Phillips successfully completed Phase II this year. Performance of the Phillips generator-absorber heat exchange (GAX) cycle was measured with two candidate absorption fluid combinations, ammonia-water and ammonia-lithium bromide-water (ternary). The GAX cycle breadboard achieved coefficient of performance (COP) values (fuel-based) of over 1.8 in heating and 0.8 in cooling, exceeding the original goals of 1.6 for heating and 0.7 for cooling.

Based on these successful results, Phase III work was initiated at Phillips in 1986 to build an ammonia-water GAX packaged prototype. Phase II breadboard testing of the Trane advanced cycle and Phase III prototype testing at Phillips are scheduled in the coming year. Figure 4.1 shows the laboratory equipment under construction at Trane to demonstrate proof-of-concept of their advanced absorption cycle.

ORNL researchers have identified new absorption fluids and cycles with performance potential substantially beyond that of the current subcontracts, which may form the basis for the next generation of absorption equipment development. One of these new cycles, a triple-effect absorption heat pump, has a calculated performance potential that is 30–50% more efficient than the best existing double-effect absorption chillers. The cycle is best suited to systems >176 kW (50 ton) and is therefore a candidate for medium and large commercial buildings. The cycle requires less overall heat transfer surface than a conventional double-effect chiller, which should result in lower first costs as well. Patents were filed by DOE on an expedited basis during the last year on these advanced absorption cycles. It is expected that development work on these new cycles will start shortly.

The absorption program also includes supporting research on fluid properties, advanced instrumentation, heat and mass transfer, computer simulation models, and fluids pump development. The Institute of Gas Technology completed work in a data survey[1] for U.S. absorption fluids properties, and an international agreement on absorption fluids data cooperation was implemented. The ORNL Analytical Chemistry Division has continued development of a unique fiber optics instrumentation system to extend its capability to other absorption fluids such as ammonia-water. A patent was filed this year by DOE on the device, which measures fluids concentration in an absorption machine in real time. ORNL has also initiated a project on the dynamics of heat and mass transfer with emphasis on enhancement techniques for absorber performance.

Technion Institute of Technology developed and validated an absorption cycle computer model that has been transferred to ORNL and several of the contractors for future cycle analysis work.[2] The model has been used to evaluate several new advanced cycle concepts for residential and commercial HVAC equipment and for industrial temperature boosters. It has several different absorption fluids built in and can model advanced absorption cycles that simultaneously use more than one absorption fluid combination.

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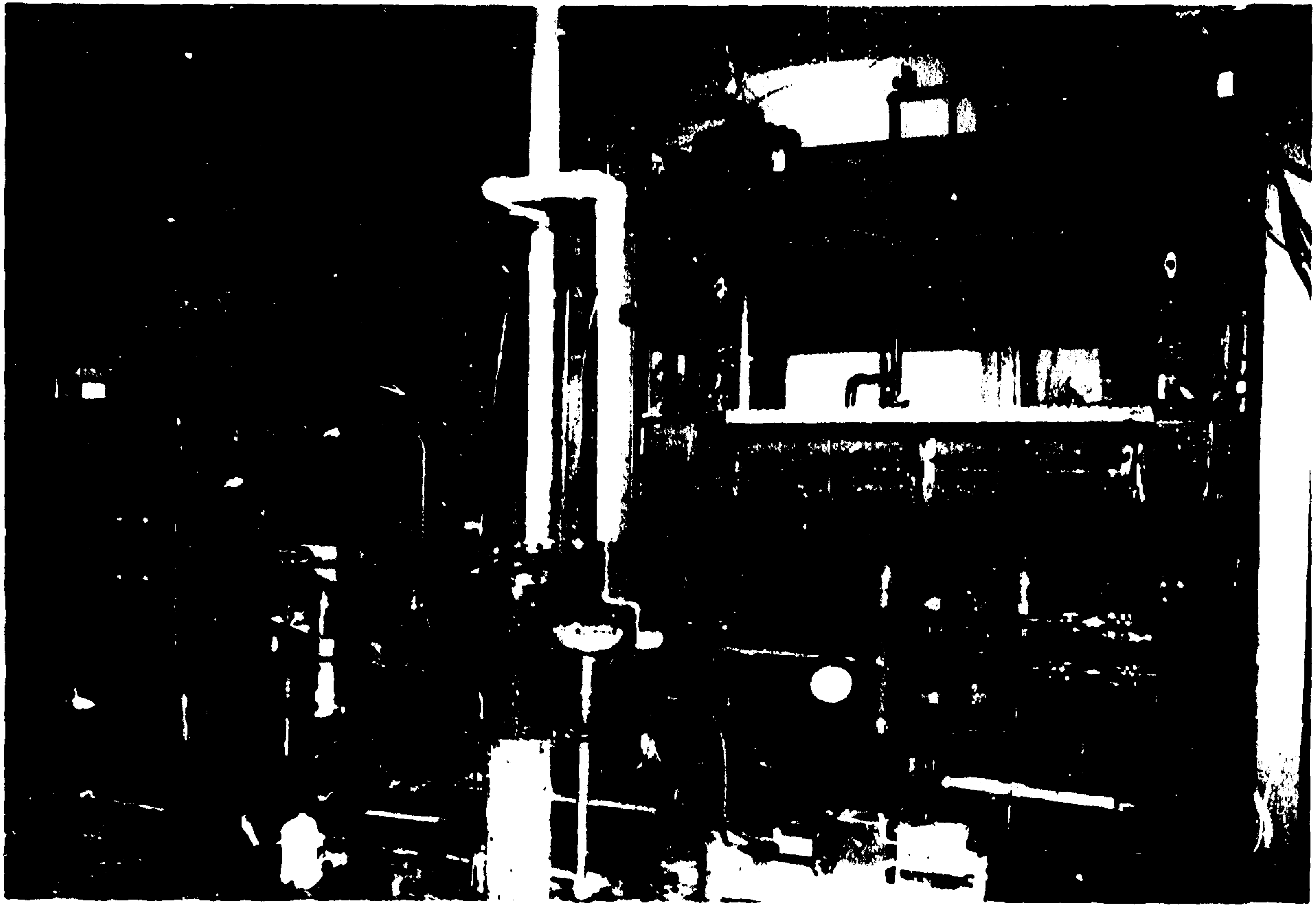

Fig. 4.1. Trane advanced absorption cycle breadboard.

A project was also started on development of a new, long-life solution pump, a critical component needed for residential-scale absorption equipment. The potential application of new ceramic materials in high-efficiency gear pumps will be proof-tested in the next year.

The work on Stirling engine-driven heat pumps is focused on the free-piston Stirling engine (FPSE), with the principal thrust being transmission/compressor (T/C) development. Under the BER program, Mechanical Technology, Inc. (MTI), has developed a diaphragm-actuated, hydraulic T/C over the past several years.[3,4] This is a collaborative effort with GRI, in which GRI supports a parallel FPSE development project at MTI.

Technical feasibility of the FPSE-driven heat pump concept was proven this year with successful coupling of the FPSE to an externally balanced configuration of the T/C. The T/C achieved an 85% transmission efficiency and 75% compressor efficiency, and the Mark I FPSE developed for GRI reached design power output in breadboard heat pump tests. Various improvements during the past year have improved cooling COP from 0.61 to 0.86, while heating COP has risen from 1.35 to 1.61. In addition, system capacity has been increased from 8.8 kW (2.5 ton) to 11.3 kW (3.2 ton). During the coming year, the complete engine/T/C assembly will be sent to Lennox Corporation for further testing and performance "mapping" across a wide range of operating conditions. In addition, alternative T/C design concepts that could offer reduced complexity and lower first cost will be evaluated.

An international cooperative project with Japan and Sweden was initiated through the International Energy Agency (IEA) to comparatively assess free-piston and kinematic Stirling engine-driven heat pump technology. Another supporting research project initiated in the past year with Massachusetts Institute of Technology is aimed at improving the integration of experimental work with the analytical and theoretical work by proper selection of variables that are both useful in computer simulation and measurable in experiments. Effort also continued on the ongoing support project with the National Aeronautics and Space Administration, Lewis Research Center (NASA LeRC). Experimental investigations at NASA LeRC have focused on characterizing FPSE efficiency and power as related to key design variables, and a new hydraulic load simulator has been built and installed at NASA LeRC to study engine/load interactions with the well-characterized RE-1000 engine from Sunpower, Inc.

Development work continued on a TAHP system driven by a Braun linear engine, a free-piston IC engine. Successful performance results have been achieved in testing by the development contractor, Tectonics Research, Inc.[5] Under a new subcontract with Minnesota Gas Company (Minnegasco), gas utilities have started sharing the development cost and have agreed to further support field evaluation tests planned for next year. This project also involves Northern Natural Gas Company and Mammoth Division of Nortec, Inc., a manufacturer of commercial-sized HVAC equipment. These activities are described in more detail in Sect. 4.2.1.

Several novel TAHP cycles and concepts were identified in surveys and evaluated by ORNL staff to determine whether they merit further research. Two such concepts selected for further study are a hybrid engine/desiccant heat pump system and an enhanced ejector flow mixing technique.[6]

4.1.1.2 Refrigeration systems

Considerable progress has been made in both the analytical and experimental phases of heat pump capacity modulation research at ORNL. Laboratory tests were conducted to investigate optimal combinations of compressor speed, blower/fan speed, and flow-control orifice size. A refrigerant charge inventory model was developed and incorporated into the steady-state heat pump computer model. Work is well under way to upgrade and modify the computer-aided design analysis programs for variable-speed heat pump systems. Close interaction with the HVAC industry through the Air Conditioning and Refrigeration Institute and through cooperative agreements with individual manufacturers is an important and integral part of the capacity modulation effort. These activities are discussed further in Sect. 4.2.2.

Nonazeotropic refrigerant mixtures (NARMs) have been identified as a means to improve thermodynamic cycle efficiency in vapor compression equipment and as an attractive capacity modulation option. In the BER program, the basic approach is to demonstrate experimentally the benefits of mixtures and to develop a firm analytical base for system design. In prior years, measurements of efficiency improvements in existing or slightly modified equipment have led to the conclusion that systems using NARMs will require custom design to obtain the potential thermodynamic benefits. One such new flexible test loop with capability to simulate custom design features was installed this year at U.S. National Bureau of Standards (NBS) and is now operational. The NBS test apparatus is shown in Fig. 4.2. It is being used for experiments in which the thermodynamic cycle efficiency benefits are optimized by a combination of mixture selection and cycle/hardware modifications. A second loop will be operated at ORNL to evaluate modulating cycle concepts. Fabrication of the ORNL test rig is under way at an outside vendor, Vista Scientific.

The projects in ground-coupled heat pump (GCHP) technology are nearing completion except for technology transfer activities. This year, research centered on a design optimization project for northern climate applications with limited work on analytical models for ground-coil heat exchangers. Two GCHP systems based on the optimized system design philosophy were field tested in Syracuse, New York, under a cost-shared subcontract with Niagara Mohawk Power Corporation. The installations used the prototype water-source heat pump (WSHP) built by Friedrich based on analytical results from the prior GCHP system design optimization cooperative project between ORNL, Brookhaven National Laboratory, and Friedrich-Climate Master. Results of the field evaluation were favorable, verifying that by utilizing a more efficient WSHP package, the ground coil size can be reduced at least 30% (compared to standard practice) without sacrificing overall GCHP system performance. This can lead to reduced payback periods of 2–5 years for optimized GCHP systems vs air-source heat pumps, whereas payback periods of 5–10 years are typical with standard GCHP design practice.

4.1.2 Industrial Chemical Heat Pumps

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The CHP Program, a part of the DOE Industrial Heat Pump (IHP) Program, encompasses various mechanical as well as CHP concepts. The intent of the program is to enable the

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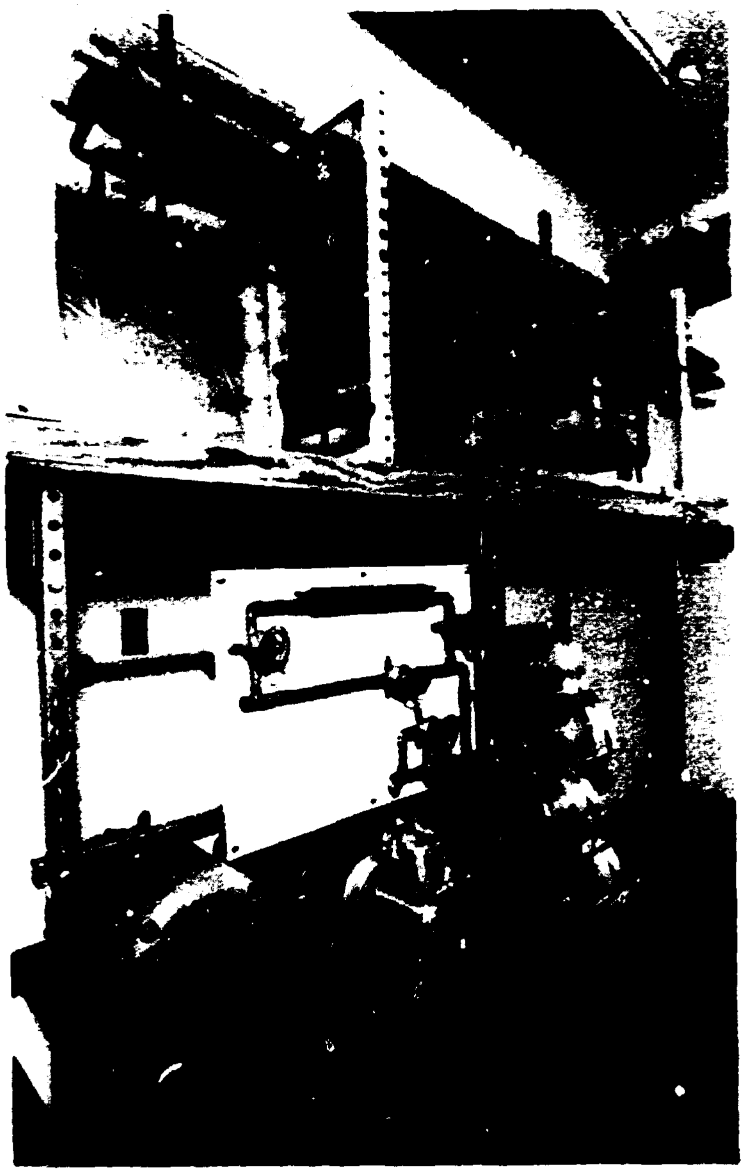

Fig. 4.2. NARM test rig at NBS.

conservation of national fuel resources by recovering, upgrading, and recycling in-plant thermal energy that would otherwise be rejected in industrial processes. The amount of energy thus recoverable is estimated to exceed 3 quads (3.2×10^{15} kJ) annually.

The ORNL program relates to Heat-of-Mixing CHPs (HMCHPs). These are driven by thermal rather than mechanical energy and occupy a particular economic niche in the IHP spectrum, showing lifetime cost superiority where high operating temperatures and large temperature lifts are required. The particular industrial applications where these characteristics can most appropriately be used are being identified by another segment of the national IHP program. Because of the diversity of process applications, industrial HMCHPs are more appropriately assembled by architect-engineer firms rather than being manufactured on an assembly line.

Consequently, any investment by U.S. manufacturers of large heat pump and refrigeration equipment in long-range research for future market opportunities will be limited, at least until the market for large heat pump components is better defined. Thus, our role is to perform the necessary exploratory research so that a workable HMCHP technology can be transferred to the industrial sector for implementation.

ORNL directs and participates in investigating and characterizing HMCHP operating cycles and working media and in developing system concepts that will function economically in process situations, as these are identified.

A survey and assessment of chemical heat pumps, largely carried out in 1985, was completed and published.[7] This document discusses the potential for CHPs in industrial energy conservation, reviews CHP operating principles, and describes the worldwide status of CHP development for industrial purposes.

Computer codes were constructed[8–10] for (1) calculating the performance of single-stage and multi-stage liquid/vapor CHP systems employing any arbitrary refrigerant-sorbent fluid pair and (2) optimizing the distribution of heat exchanger area in the system to minimize life cycle costs. To aid in evaluating the potential limits of CHP performance, equations were constructed describing the thermodynamic properties of ideal CHP working fluids.[11] Sets of optimum physical and thermodynamic properties for working pairs to be used in heat-amplifier or in temperature-amplifier cycles, respectively, were determined.

Two subcontractors were selected to identify and characterize working fluid pairs that would enable CHPs constructed of inexpensive alloys or mild steel to operate up to at least 250°C, with a temperature lift of 65°C or above. Desert Research Institute[12] of the University of Nevada examined both inorganic and organic fluid pairs and selected trifluoroethanol (TFE) and E-181 (E-181 is also known as Tetraglyme or DMETEG—dimethyl ether of tetraethylene glycol), respectively, as the refrigerant and absorbent. The mixture is stable up to 250°C in the absence of air, and the calculated maximum lift is approximately 80°C in a single-stage temperature-amplifier cycle. Energy Concepts Company,[13] of Annapolis, Maryland, developed an aqueous mixture of lithium, sodium, and potassium nitrates that is stable at temperatures well above 260°C and promises an even higher lift than that of TFE/E-181. Details of these fluid pairs are discussed as a technical highlight in Sect. 4.2.8.

4.1.3 Building Thermal Envelope Systems and Materials

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The Building Thermal Envelope Systems and Materials (BTESM) Program was initiated by the Building Systems Division of DOE in response to an expressed need of the buildings community

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for more relevant technical information on the thermal performance of building envelope systems and in recognition of the impact that improved thermal performance of buildings would have on energy conservation, importation of fuel, and the economic health of the nation. The objective of the program is to provide the technical data, test procedures, guidelines, and consensus standards needed by manufacturers, designers, and builders to produce buildings of high energy efficiency while concurrently meeting safety, durability, habitability, and economic requirements. The program also incorporates the activities needed to introduce these technical products into the commerce of buildings. The scope of the research anticipates participation and cost sharing between government and industry in carrying out the objectives of the program.

Tasks within the BTESM program at ORNL include Buildings Materials (within the Metals and Ceramics Division), which covers research on materials science, materials applications, and test procedures; Walls and Foundations Research, which covers work on energy efficient wall and foundation systems, performance analysis of systems, envelope thermal anomalies, and thermal mass; Roofs and Building Diagnostics, which includes research on the thermal performance and durability of insulated waterproof roof systems and on instruments and techniques for building performance measurements; and Implementation, which addresses cross-cutting technology transfer issues, provides managerial support, and carries out special requests from DOE sponsors.

The Roof Thermal Research Apparatus, shown in the foreground of Fig. 4.3, is the center of an active project to investigate the thermal performance of low-sloped roofs under in-service conditions. During FY 1986, data have been gathered on transient behavior, the effects of surface reflectance and surface mass, and the characteristics of several techniques for making thermal measurements and for analyzing thermal performance data. A presentation of an analysis technique for determining the thermal resistance of a roof from in situ data is given in Sect. 4.2.4. Analysis of these issues will be completed and published in FY 1987.

The new building to house the Large Scale Climate Simulator (LSCS) is seen in the background of Fig. 4.3. The LSCS (shown schematically in Fig. 4.4) is under construction and scheduled for delivery in October 1987. In this device, roof test specimens can be exposed to a wide range of controlled, simulated weather and interior conditions while accurate, real-time measurements of thermal, moisture, and mechanical characteristics of the specimen are being made.

ORNL staff, in conjunction with an Industry Advisory Panel, have completed a review of current foundations research.[14] This document identifies and places priorities on specific projects. In addition, a project has been started to develop a handbook on energy efficient foundation design practices, and ORNL has provided analytical techniques for estimating foundation heat losses to an American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) committee on building standards. This foundations research is included as a technical highlight in Sect. 4.2.3.

Other activities during FY 1986 include the completion of a preliminary study of high-R-value, evacuated-powder insulation boards,[15] the completion of an extensive field study on the settling of loose-fill attic insulation, and the continuation of research to characterize the performance of radiant barrier insulation systems and a compilation of thermal physical properties of masonry building materials. In addition, a methodology to characterize building envelope thermal bridges has been identified and will lead to an FY 1987 project to develop an information manual for designers. Prototype instruments have been developed for determining the thermal integrity of a building envelope from measurements of interior temperature decay and for determining the seasonal efficiency of combustion system heating units. Work is also under way on devices to measure moisture concentrations in roofs and on techniques to improve the reliability of heat flux transducers.

ORNL-PHOTO 6094-86

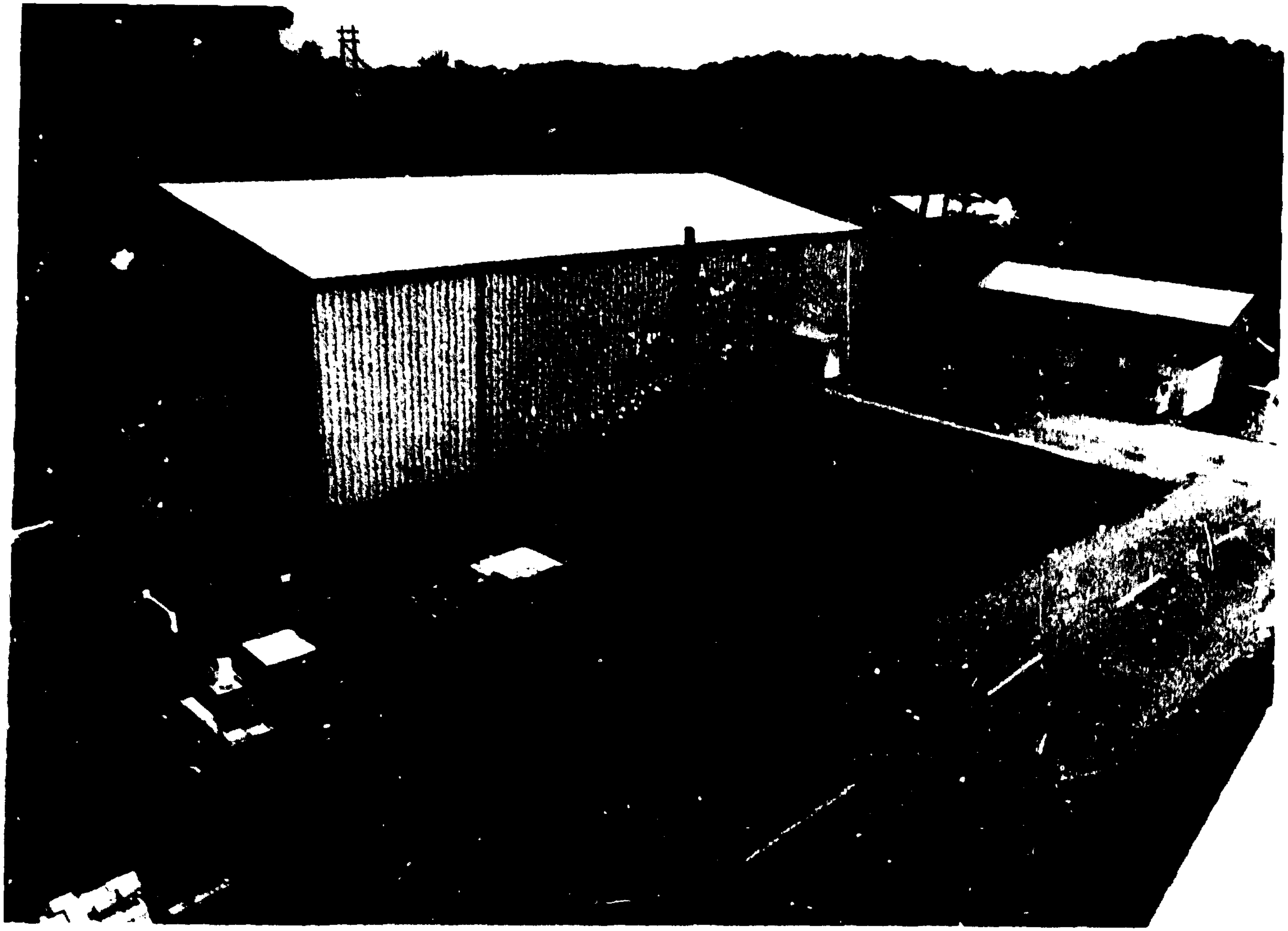
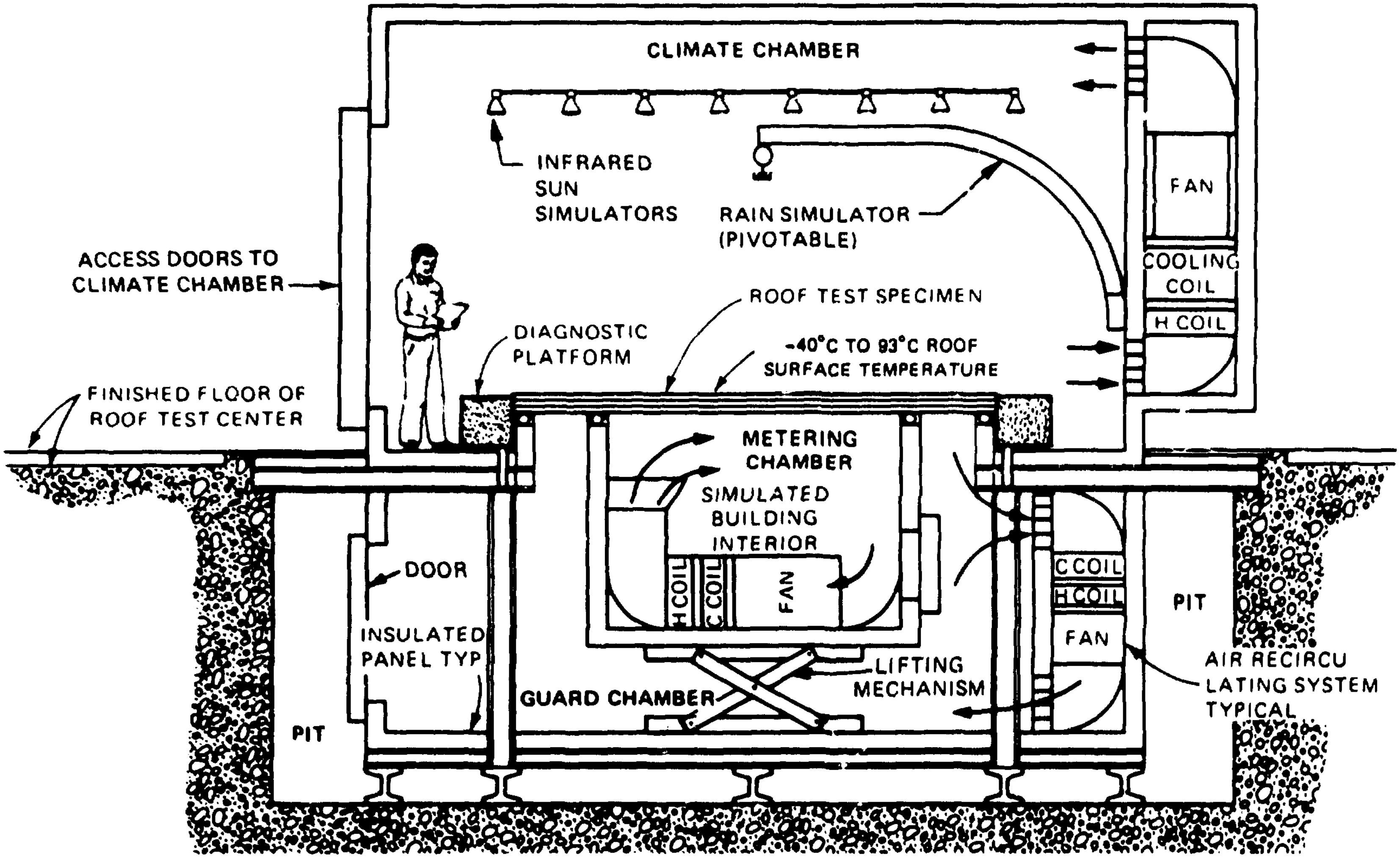


Fig. 4.3. Roof Research Center Facilities.

ORNL-DWG 85-10706R3



DESIGN CONCEPT

Fig. 4.4. Large-scale climate simulator.

4.1.4 Residential Conservation Service and Retrofit Research Programs

W. R. Mixon*

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Research focusing on technical and program implementation issues for improving the energy efficiency of existing buildings is included in two programs for DOE: the Residential and Commercial Conservation Program (RCCP) for the Office of State and Local Assistance Programs and the Buildings Energy Retrofit Research Program for the Office of Buildings and Community Systems. The RCCP originally included the Residential Conservation Service (RCS) and the Commercial and Apartment Conservation Service (CACS), which were established by law to facilitate use of energy-conserving retrofit measures in residential and small commercial buildings. During FY 1986, legislation was passed that repealed CACS, added multifamily buildings to RCS, and increased the flexibility of states to design and implement alternative programs. ORNL is continuing to provide support for program planning and rulemaking; technical assistance to DOE, states, and utilities for program implementation; evaluations of costs and benefits of selected RCS and alternative programs (described in Chap. 6); and technical assessments of conservation potential.

The Buildings Energy Retrofit Research Program grew from research previously conducted only in support of RCS and CACS and was officially established in FY 1985, with lead roles assigned to ORNL for single-family and commercial buildings and to Lawrence Berkeley Laboratory (LBL) for multifamily buildings. Increased emphasis on retrofit research stems from evidence that the greatest potential for energy savings from conservation programs in the next 15 years is in the retrofit of existing buildings and that the adoption of conservation measures is inhibited by a variety of technical, behavioral, and market-related problems.

The RCCP and retrofit research programs involve cooperative effort with the Solar Energy Research Institute (SERI), Battelle Pacific Northwest Laboratory, and LBL and the active participation of the Engineering Technology Division and the Information Resources Organization of ORNL.

4.1.4.1 Residential Conservation Service and Commercial and Apartment Conservation Service programs

The primary activities for the year included validation studies of automated audit procedures proposed for standard use by CACS program participants and review of CACS plans submitted by

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[¶]Group Leader.

participants. With the cancellation of the CACS program, the plan review activity was stopped. However, the audit validation work should still prove useful to states that typically do not have the resources required to evaluate all the procedures available. The validation studies represented a first step in a public quality assurance process that evaluated the algorithms and data proposed for use in the automated procedures to make sure they were consistent with state-of-the-art knowledge.

Under the wider scope of the RCCP, a multiyear plan was developed with SERI that included estimates of the remaining energy savings that could be achieved through residential and commercial conservation programs.

4.1.4.2 Commercial retrofit research

Projects for the past year have been aimed at establishing a foundation for proceeding with obtaining energy performance data on commercial buildings though field experiments.[16] This includes having a better understanding of the sector itself, which is quite diverse, and developing procedures for obtaining the field data. Field experiments are scheduled to start next year.

The DOE-2 cod is being used in a modeling task to develop a basis for categorizing office buildings. Case studi... varying building type, location, HVAC equipment, lighting, occupancy, equipment, insulation, glass, and heating fuel were run to characterize energy use in commercial buildings.

Energy use in commercial buildings is also being explored using information contained in the Nonresidential Buildings Energy Consumption Survey (NBECS) data files. Unfortunately, the NBECS data only provide information on total energy use. Work is under way to extrapolate that information to provide estimates of heating and cooling energy use for different types of systems and building types.

A field-monitoring protocol to be used for commercial buildings is also under development. The protocol describes what data should be taken to answer various questions related to building performance and how that data should be analyzed. A major benefit of adopting such a protocol is that it allows comparison of performance across buildings and climates.

4.1.4.3 Single-family retrofit research

The objectives of the Single-Family Retrofit Research Program are to determine the energy savings that can be achieved through various conservation retrofit measures and to support private sector efforts in implementing and monitoring single-family residential conservation retrofits. The main activities completed during the year were (1) the development of a field-monitoring protocol, (2) experimental tests to determine the energy savings brought about by the installation of radiant barriers in attics of single-family houses, (3) a field-monitoring experiment in 100 houses in Wisconsin (see Sect. 4.2.5), and (4) issuance of a Request for Proposals to solicit interest of states and other organizations in field monitoring of retrofits.

The emphasis of the work is on field performance monitoring of conservation retrofits.[17] The radiant barrier tests continued at the Karns House Test Facility--three identical unoccupied houses located on the same site in Karns, Tennessee. Two methods for installing radiant barriers were tested. One method was to lay the radiant barrier on top of the attic fiberglass insulation; the other was to attach it to the underside of the roof trusses. The cooling electric consumption data showed a 17% savings for the house with the horizontal barrier and a 9% savings for the house with the truss barrier.[18] The results for the heating season tests showed that the horizontal barrier was able to save electric energy in both the resistance and the heat pump modes amounting to 10.1% and 8.5%, respectively. The results for the roof truss barrier showed an increase in heating electric use of 2.6% in the resistance mode and 4.0% in the heat pump mode. The field test shows the horizontal installation to be the more energy efficient use of the barrier. The reflective foil costs about $150 installed in a typical 112-m^2 (1200-ft^2) house. The annual savings for the Knoxville climate in a house with R-19 attic insulation at current energy prices would be approximately $75. Therefore, the simple payback would be approximately 2 years.

4.1.5 Power Systems Technology Program

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J. D. Birdwell[§]	P. S. Hu	M. D. Morris[‡‡]	R. A. Stevens
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L. G. Christophorou[†]	D. M. Kroeger[¶]	W. R. Nelson	G. R. Wetherington[‡]
S. J. Dale	R. J. Lauf[¶]	M. O. Pace[§]	R. K. Williams[¶]
C. Easterly[†]	J. S. Lawler	J. H. Reed	H. A. Wright[†]
T. L. Ferrell[†]	R. A. Mathis[†]	D. T. Rizy	

The Power Systems Technology Program (PSTP), supported by the DOE Office of Energy Storage and Distribution, has six major work areas: electromagnetic pulse, biological effects of high-voltage transmission, materials, high-voltage transmission, dielectrics, and system automation and control. The program is a blend of in-house studies and subcontracts involving private industry (consultants and manufacturers), the electric utility industry, and universities, with the objective of contributing to the solution of future, complex electric utility system problems. The strategy for solving problems encompasses a combination of studies, computer modeling, laboratory experiments, and field installation of experiments. The Energy Division has lead responsibility for the program; however, key roles have been assigned to Energy Systems Engineering and to the Health and Safety Research, Instrumentation and Controls, Metals and Ceramics, and Solid State divisions of ORNL.

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4.1.5.1 System automation and control

A major part of the systems research is concerned with end-use technologies, including research on distribution automation. Distribution automation uses (1) communication and control between the utility and end-use devices to manage equipment capacity more effectively and (2) a real-time control system to reduce peak demands and power loss in lines and transformers. Equipment installation for a large-scale distribution automation and load management experiment is almost complete. The experiment is being conducted in collaboration with the Athens Utilities Board (AUB) on the distribution system at Athens, Tennessee.[19-21] EPRI has furnished some load measurement equipment for installation in the AUB customers' homes. This experiment is described more fully as a technical highlight in Sect. 4.2.6.

Power Systems Information Management,[22] a concept much more advanced than the Athens experiment, holds promise of significantly improving the operation of electric utilities, improving their ability to operate reliably under emergency conditions, and improving the flexibility to integrate into their systems new technology options such as load management and distribution automation as the technologies become available. A 5-year program plan has been prepared on the integration of data processing equipment, advanced communication techniques, and advances in information science and technology into the electric utility industry.[23]

Projects to advance the art of adaptive protection relaying and artificial intelligence applications to power system management are in place with the University of Tennessee, Virginia Polytechnic Institute, and Energy Research & Management, Inc. The studies are developing the requirements of a conceptual adaptive protection system that (1) is responsible for protection, control, alarm, and monitoring of a power system; (2) improves system performance in the face of disturbances; and (3) accommodates existing protection equipment that may not have suitable interface for an adaptive system.

A tutorial session entitled "Can Relays Adapt—Can Relay Engineers Adapt?" was presented by Electric Research & Management, Inc., and Virginia Polytechnic Institute at the Institute of Electrical and Electronic Engineers (IEEE) Power System Relaying Committee Meeting in Denver during the year. The purpose of the tutorial session was to present some of the adaptive transmission system protection functions being developed in the two studies, to present preliminary ideas on the organization (i.e., computer hierarchy and communications) of adaptive protection systems, and to get some utility feedback on the concepts.

In the Computer-Aided Systems and Control Analysis and Design Environment (CASCADE), software has been designed by the University of Tennessee to increase the efficiency of design engineers and theoreticians in an interactive environment.[24,25]

Also in progress is a project to develop a low-cost inverter that produces a high-quality AC output for connecting photovoltaic systems to an AC electric power distribution system. Three prototype inverters have been built and successfully tested as part of a subcontract with Helionetics, Inc., of Irvine, California. Studies to identify possible functions that could be performed by microprocessor are being completed and a prototype controller has been installed in one of the inverters.

A research subcontract is in place with the McGraw-Edison Company to determine the effect of harmonics on power distribution systems. A design manual has been prepared by the McGraw-Edison Company to help utility system operators analyze and control harmonic distortion on distribution feeders. Three seminars were held during the year to acquaint distribution system engineers with the harmonics problems and to describe ways to ameliorate them. The final report for the initial phases of this project has been prepared and is currently being edited for publication as an ORNL subcontractor's report.

A subcontract is in place with the University of South Carolina to analyze field data collected by TVA in the vicinity of 500-kV transmission lines and to develop a statistical model of actual field strengths under transmission lines, including effects of vegetation and terrain. The TVA data have been tabulated into a data report and published as an ORNL subcontractor's report.[26] A report on the work was given at the IEEE Transmission and Distribution Conference in 1986.[27]

A project with the Phoenix Electric Company to design, develop, manufacture, and test a current-limiting protector (CLP) using a unique pyrotechnic current commutating scheme has been completed. The CLP is designed to limit fault current to 40,000 A on a 330,000-A RMS fault. The CLP's application is useful for the protection of electrical apparatus where high voltage and very high short-circuit current are experienced. The final report has been written and is being issued as an ORNL report.[28]

4.1.5.2 Biological effects of high-voltage transmission

The Health and Safety Research Division at ORNL is assessing potential health risks associated with high-voltage transmission lines. A handbook of epidemiological methods, with special emphasis on extremely low-frequency electromagnetic fields, was issued.[29] The handbook is directed to electrical utility managers and others interested in the possibilities of becoming involved with an epidemiology study.

A new exploratory study of high-voltage DC ion chemistry has been initiated in the Health and Safety Research Division at ORNL to provide information on ion reactions near high-voltage DC lines. Another new program has been initiated in the Health and Safety Research Division to investigate the toxic activity of SF_6 gas and its decomposition by-products in in vitro systems. Preliminary results indicate that some decomposition products are lethal to mammalian cells.

4.1.5.3 Dielectrics

The dielectric materials research and development (R&D) program is intended to further the fundamental understanding of these materials and to provide a data base for the development and application of materials for future electric power equipment that will have improved efficiency and reliability.[30]

A 50,000-h test has been completed as part of a study conducted by the Metals and Ceramics Division at ORNL to characterize the mechanical, electrical, and thermal properties of seven polymers in the presence of SF_6 and insulating oil. The polymers are being studied to obtain information on long-term degradation mechanisms under multifactor stresses. The data obtained will provide guidelines and design parameters on compatibility, utilization, and selection of polymers for electrical insulation systems.

4.1.5.4 Electromagnetic pulse

A study to assess the effects on the U.S. power system of electromagnetic pulse from a nuclear explosion is now being conducted.[31] This study is in response to concern about the national security aspects of such an occurrence. This subject is covered more fully as a technical highlight in Sect. 4.2.7.

4.1.5.5 High-voltage transmission

The High-Voltage Transmission Program encompasses R&D on high-voltage DC transmission and new concepts for high-voltage AC transmission. The high-voltage DC research is intended to further develop and improve an important energy transport technology, one that will offer many opportunities to reduce future energy costs.

The PSTP is also conducting R&D on high-phase-order AC transmission lines. This technology, which is being developed at Power Technology, Inc., can increase power transfer through existing corridors by using 6-phase and 12-phase transmission lines instead of the conventional 3-phase transmission line technology. The work in this area is near completion. The New York State Electric and Gas Company is considering installation of a 6-phase demonstration line between two of their substations. The New York State Energy Research Administration and the Empire State Electric Energy Research Corporation will share in funding the project.

Research continues on the relationship between the electric fields and voltages induced by lightning on overhead power distribution system structures. The purpose of this work is to determine a more accurate relationship between electric fields and voltages induced by lightning on overhead electric power distribution system structures. This is a 4-year study that will involve both field measurements and analyses. During the summers of 1984–1986, field studies were conducted at the Kennedy Space Center (KSC) to measure the time-domain horizontal and vertical electric field components due to lightning as a function of lightning range and earth conductivity and permittivity. Measurements of lightning-induced voltages on an unenergized distribution feeder at the KSC were conducted during the summers of 1985 and 1986. In 1987, The University of Florida will make simultaneous measurements of electric fields and power line voltages at both ends and the middle of an unenergized distribution feeder for a variety of line terminations for both very close natural lightning and artificially initiated lightning. Analysis work is reexamining present theory relating electric fields and voltages induced by lightning on overhead distribution lines and will develop a more accurate relationship between them. This work is important because significant discrepancies exist between the theory of induced voltages on distribution feeders due to lightning and earlier field measurements of the horizontal component of the electric field.

Studies to determine the technical feasibility of a high-voltage DC compressed-gas-insulated transmission line have been completed by the General Electric Company and Westinghouse Electric Corporation. The objective of these studies has been to develop high-voltage test methods for high-voltage DC compressed-gas-insulated cables and substation equipment. These concepts will allow economical transmission of electric power underground and will result in space-saving, aboveground, right-of-way designs. Final reports on these two projects are now being prepared.

A 118-m, 1200-kV semiflexible cable manufactured by the Westinghouse Electric Corporation under a DOE contract has been installed at EPRI's high-voltage test facility. Long-term-life tests have been conducted on the cable for over a year and are continuing.

4.1.5.6 Materials

A materials program is in progress in the Metals and Ceramics and the Solid State divisions to develop a fundamental understanding of conduction and breakdown of semiconducting metal oxides that are now being used or could be used in a variety of voltage surge suppression applications.[32] Zinc oxide (ZnO) blocks fabricated by the ORNL Metals and Ceramics Division from a new sol-gel process have been furnished to The University of California under a subcontract with ORNL to develop a concept of using ZnO varistors imbedded in an overhead line insulator as a method to improve performance and reduce insulation clearance of high-voltage overhead lines.

Fundamental studies on the embrittlement of amorphous metals are now in progress in the Metals and Ceramics Division. The objective of this program is to develop a method of fabricating amorphous metal cores that have outstanding magnetic properties for electrical equipment in which the embrittlement during processing can be eliminated, thus allowing more advanced designs and easier fabrication of equipment. Research has shown that the problem of embrittlement in amorphous metals can be minimized by modifying the alloys to increase the temperature at which embrittlement occurs above that needed to optimize magnetic performance. This modification is accomplished by microadditions of cerium to the material, which is melt-spun into ribbons. The retardation of embrittlement during annealing of cerium-doped ribbons has been shown to be reproducible and not strongly dependent on ribbon geometry, surface condition, or cooling rate. X-ray diffraction examination of doped ribbons has shown that cerium addition reduces the degree of crystallinity in the as-quenched ribbon. Tests with other elements having strong affinity for oxygen and/or sulfur have demonstrated that the role of microalloying is to control the concentrations and distributions of impurities.

4.1.6 Work for Others

4.1.6.1 DOD energy conservation programs

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Projects under way for the U.S. Army Facilities Engineering Support Agency include (1) validation of energy and cost savings for selected retrofit projects under the Energy Conservation Investment Program (ECIP) and (2) evaluation and/or testing of energy conservation devices and equipment in conjunction with the Army Conservation Equipment Test Program.

Two ECIP validation studies were completed during the year. The first was a study designed to validate energy and cost savings attributed to roof insulation retrofits at Fort Filey, Kansas. Insulation was added to the roofs of 16 buildings that had no ceiling or roof insulation before retrofit. The validation procedure consisted of modeling both preretrofit and postretrofit energy use of four buildings, supplemented by submetered space heating fuel use. The modeled savings for the 4 buildings were used to extrapolate the results to all 16 buildings.

Based on these energy savings, life-cycle cost analyses were performed resulting in a projected savings-to-investment ratio (SIR) of 2.41 for the entire project of 16 buildings.

The second ECIP project completed was an analysis of savings resulting from the installation of a wood burning boiler plant at Fort Stewart, Georgia. During the postretrofit validation study period (FY 1986), the new wood-burning boiler produced approximately 90% of the steam required

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by the central energy plant to meet the seasonal heating and cooling demands of Fort Stewart. In doing so, over 10,900 m^3 (2,880,000 gal) of No. 5 fuel oil was conserved. Based on the results of a life-cycle cost analysis, a first-year savings of over $1.2 million was estimated. The resultant discounted SIR is 3.36, with an estimated payback period of 6.7 years.

4.1.5.2 EPRI Ice Storage Test Facility

M. A. Kuliasha, J. J. Tomlinson,* D. J. Fraysier*

EPRI is funding a facility at ORNL to test commercial ice storage equipment according to a uniform testing procedure. The objectives of the testing are to produce validated performance data and design recommendations for cool storage installations. Scheduled to take about 3.5 years, the project includes the design and construction of a test facility and testing of four cool storage systems, including a dynamic ice maker, a direct expansion ice-on-coil system, a flooded ice-on-coil system, and a secondary loop system. The scope of the project also includes organizing two workshops for manufacturers, designers, installers, and utilities to present the testing results and recommendations. The accomplishments of this project are presented as a technical highlight in Sect. 4.2.9.

4.2 TECHNICAL HIGHLIGHTS

4.2.1 Linear Internal-Combustion-Engine-Driven Heat Pump Development

G. T. Privon

The effort in IC engine-driven heat pump technology is focused on one concept—the free piston linear engine/compressor being developed at Tectonics Research, Inc.

The engine, known as the Braun linear engine, is a two-stroke, loop-scavenging, valveless design with fuel injection, spark ignition, and liquid cooling of the cylinder and head. It has two moving subassemblies: the piston and rod and the balancing counterweight. The attributes that make the engine attractive are inherent in the design and consist of simplicity, low potential manufacturing cost, durability, dynamic balancing, high efficiency, and modulation of power.

The compressor consists of a piston, cylinder, valve and valve plate assembly, hermetic bellows seal assembly, and an appropriate cylinder head. The compressor piston is attached to the same rod as the engine piston. The balance mechanism between the engine and compressor results in smooth, vibration-free operation. An adjacent bounce space assists in operation and control of the engine. The compressor and bounce space act as a gas spring to return the engine piston on the compression stroke. A schematic of the engine/compressor assembly is shown in Fig. 4.5.

The engine operates at a natural resonant frequency determined by the combined effect of the compressor load and the bounce space pressure. The piston stroke varies with load conditions. Thus, by controlling the bounce space pressure and fuel intake in response to load change, engine speed and stroke can be varied.

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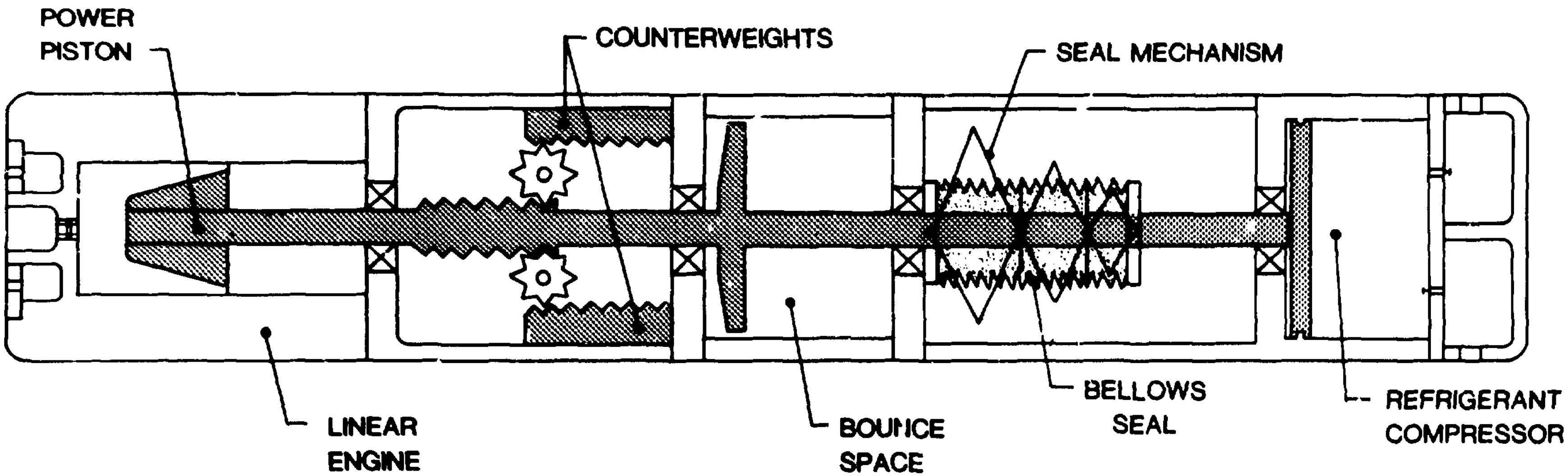

Fig. 4.5. Engine/compressor/seal assembly schematic.

In 1980, after competitive proposal reviews, contracts were issued for the development of a hermetic seal for linear motion application and development of a small commercial-sized linear engine/compressor based on the engine technology existing at Tectonics Research, Inc. These early efforts resulted in a breadboard test demonstration with propane fuel of a carbureted engine/compressor assembly operating with a hermetic bellows seal assembly.[33] The unique patented hermetic seal consists of metal bellows, a mechanism to limit bellows travel, and means of controlling the pressure differential across the bellows.[34] The seal in its final form is designed to be producible with low-cost manufacturing methods and capable of extremely long life. Figure 4.6 shows the engine/compressor with the bellows seal assembly being tested at Tectonics Laboratory. As of October 1986, 1.80 billion cycles had been accumulated on the seal bellows subassembly with a motor-driven test rig. Recent work at Tectonics has centered on testing of a modified fuel-injected engine/compressor and upgrading it to operate with natural gas and provide 52.7 kW (15 tons) cooling capability. In addition, a cost-shared program has been put in place with two gas utilities, Minnegasco and Northern Natural Gas, to evaluate the engine/compressor via laboratory and field tests of prototype heat pump units. The first phase of this "in-unit" evaluation is about to begin at an HVAC manufacturer (Mammoth).

The major achievements for 1986 were the (1) completion of a seal design for the 52.7-kW (15-ton) assembly, (2) modification of the fuel injection system to natural gas, (3) attainment of natural gas steady state COPs in excess of earlier values, (4) initiation of an independent cost analysis for the complete 52.7 kW (15 ton) assembly, and (5) shipment of an engine/compressor assembly to Mammoth for test in a unit they had fabricated.

The development of the critical bellows seal has also been done in collaboration with a manufacturer (Metal Bellows Inc.), who is furnishing the hardware.

ORNL-PHOTO 4191-87

Fig. 4.6. Engine/compressor/seal assembly test.

As shown in Fig. 4.7, the COP values for natural gas of 1.1 for 35°C (95°F) cooling and 2.1 for 8.3°C (47°F) heating are 5 to 10% greater than those obtained earlier with propane (values shown are steady-state full-load COP from breadboard tests).

Figure 4.8 shows the heat pump engine/compressor installed in the unit at Mammoth and being prepared for test.

The overall program is structured so that, if all goes well, the commercial engine/compressor/seal development efforts will be finished at Tectonics early in 1988 and the two site units will be ready for operation at about the same time. The two units will then be tested for 2 years.

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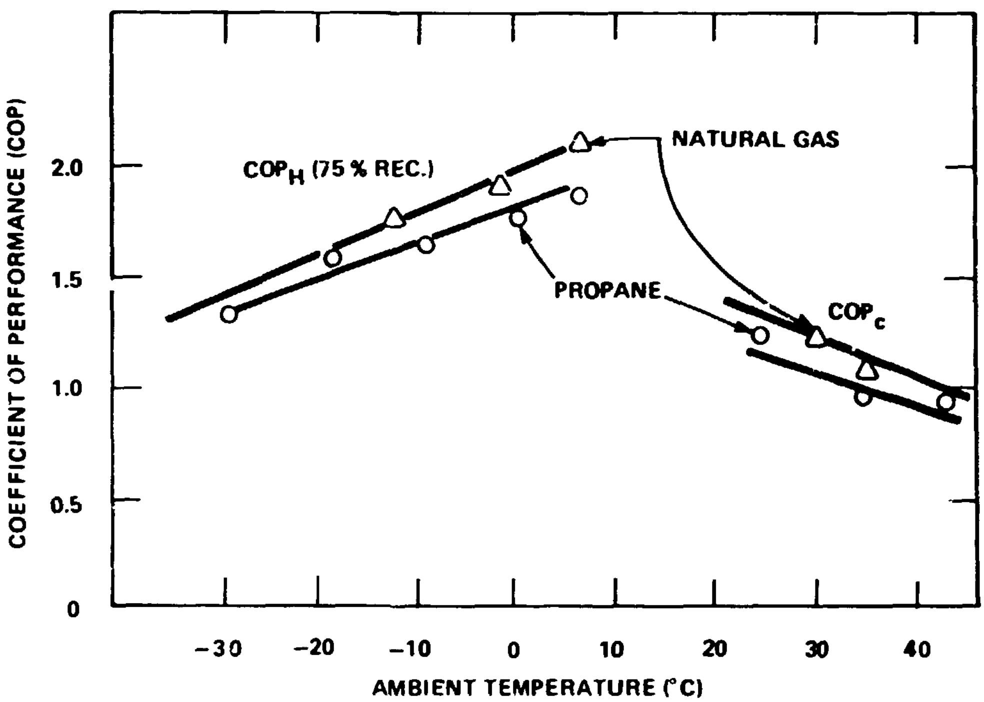

Fig. 4.7. IC engine-driven heat pump breadboard performance.

4.2.2 Heat Pump Capacity Modulation Research

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K. H. Zimmerman W. L. Jackson*

Activities in continuously capacity-modulated heat pump (CCMHP) research included (1) collaborative efforts with HVAC industry partners in modulating compressor characterization and system modeling and (2) experimental evaluation of optimal compressor and indoor fan, speed

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ORNL-DWG 4192-87

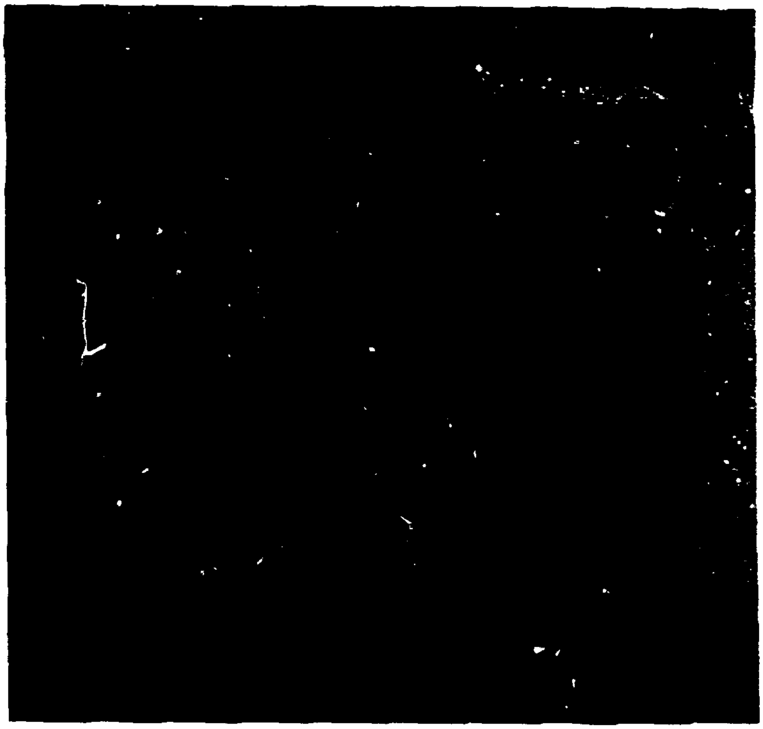

Fig. 4.8. IC engine-driven in-unit testing.

control, refrigerant control, and charging strategies appropriate for the first U.S. produced CCMHP.

4.2.2.1 Collaborative research efforts

Valuable modulating component data and/or agreements were obtained from a number of industry sources to assist in ORNL evaluations of capacity-modulation opportunities. This was accomplished through continued contacts with industry and by building upon ORNL's credibility previously established in the preliminary assessment of capacity modulation potential.[35] Data on various types of modulating compressors and motor/frequency inverter combinations has been or will be given to us in return for assistance in the transfer and use of ORNL-developed heat pump design tools and methodology.

A collaborative agreement was signed with a major U.S. compressor manufacturer to provide ORNL with modulating compressor data at ORNL-predicted speed-torque conditions for representative state-of-the-art reciprocating, rotary, and scroll compressors of residential size. The data will be obtained so as to allow the induction motor performance to be extracted, thereby providing basic information on compressor-only performance over wide speed ranges. Such compressor-only data will then be combined with performance data on advanced permanent magnet electronically commutated motors (PM-ECMs). PM-ECM data have also been obtained separately for performance evaluation of modulating indoor fans. Collectively, these data specification and gathering activities, to be completed in FY 1987, will provide U.S. industry with a shared technology base for the development of capacity-modulated heat pumps.

In engine-driven capacity modulated systems, a precedent-setting Work-for-Others collaborative agreement was signed with Borg-Warner Corporation, a GRI subcontractor. Borg-Warner contracted with ORNL to adapt the ORNL Heat Pump Design Model[36] to model a 34-kW (10-ton) kinematic Stirling engine-driven vapor compression heat pump. The resulting program provides ORNL with broadened modulating systems capability available for future TAHP assessments. Another GRI subcontractor (Battelle-Columbus) independently modified the ORNL model for internal combustion engine-driven evaluations.

4.2.2.2 ORNL experimental work

A series of heating and cooling mode tests was conducted in the laboratory to demonstrate optimal refrigerant flow and airflow control for a CCMHP installed in our test chambers. As originally purchased, the CCMHP was equipped with capillary tubes for refrigerant flow control.

The capillary tubes were replaced with variable area, hand-controlled valves for the tests. Ranges of condenser exit subcoolings (controlled by the variable area throttling valve) and indoor blower speeds for compressor speed levels ranging from 15–90 Hz were tested to observe the effect on COP, capacity, and component efficiencies. From these results, the optimal performance envelope of compressor speed, indoor blower speed, and refrigerant flow control was identified for the CCMHP unit in the laboratory.

A charging technique was developed for this study from computer modeling and from preliminary tests with the CCMHP operating at 15-Hz compressor speeds. Refrigerant was added to the system at 15-Hz operation until both low subcooling at condenser exit and low superheat at compressor inlet were obtained. This charge level was held constant for each operating mode.

Heating-mode COP measurements observed at 4.4°C (40°F) outdoor air temperature for various levels of condenser subcooling and compressor speeds are plotted in Fig. 4.9 as a function of indoor blower speed. The optimal level of condenser exit subcooling and optimal blower speed for each compressor speed are evident from the data presented. Measured COPs show an improvement in efficiency as compressor speed is reduced from 60 Hz to 30 Hz as a result of reduced blower speed and unloading of the heat exchangers. However, at 15-Hz compressor speed, the measured COP in Fig. 4.9 drops 20% compared with that observed at 30 Hz. The sharp drop in COP is the result of a loss in heat exchanger effectiveness at 15-Hz compressor speed.

Even with this loss, the COP at 15-Hz compressor speed shown in Fig. 4.9 was about 20% higher than that previously measured with capillary flow control. This increase resulted from better control of refrigerant superheat at the compressor inlet and subcooling at condenser exit obtained with the variable-area throttling valve.

Cooling mode test results at 27.8°C (82°F) outdoor temperature are shown in Fig. 4.10. These results show increasing COP from 60-Hz through 15-Hz compressor speed, a trend different from that observed in heating mode. At 15-Hz compressor speed, a condenser exit refrigerant subcooling of 5.5°C (10°F) caused COP measurements to fall below performance observed at 30-Hz compressor speed. Lowering the condenser exit subcooling to 1.5°C (2.5°F) caused an increase in COP above that measured at 30-Hz compressor speed. This improved performance is the result of reduced blower speed and improved part-load heat exchanger efficiency at 15-Hz compressor speed. Results indicate that, in cooling mode, the effectiveness of both indoor and outdoor coils remains constant as a function of compressor speed; in heating mode, the effectiveness of the outdoor coil evaporator drops sharply. This is probably the result of a higher minimum refrigerant flow rate in cooling mode as compared with heating mode.

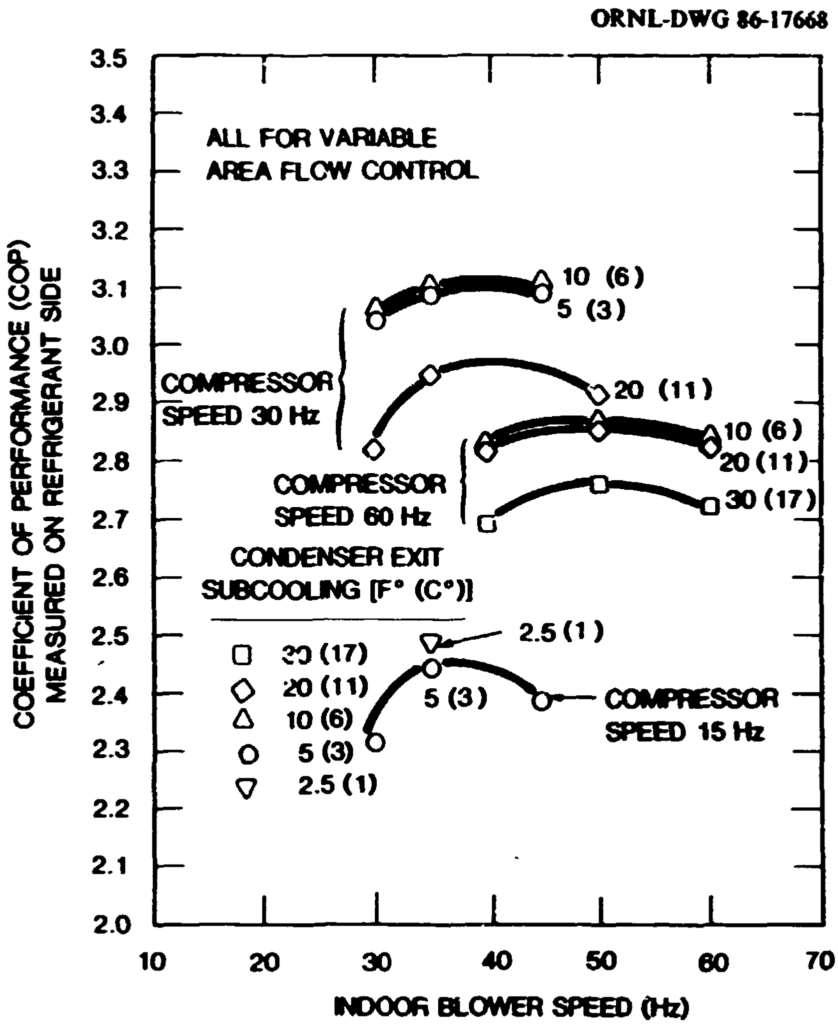

Fig. 4.9. Modulating heat pump heating performance.

Measured cooling COPs at 15-Hz compressor speed with variable-area throttle control improved greatly over previous test results with the same heat pump operating with capillary flow control. Compared with performance with the capillary flow control, the COP increased 12% and the sensible heat ratio was significantly lowered, yielding much improved humidity control.

In summary, a CCMHP charging technique was identified analytically and demonstrated in the laboratory. The optimum ratio of compressor motor speed to indoor blower motor speed, with a more optimum refrigerant flow control strategy, was identified, yielding improved efficiency as compared with previous tests with the original capillary flow control.

Data from these tests along with compressor and motor data obtained from manufacturers will be used to refine the CCMHP analytical design tools. These tools will be used in the next phase of research to (1) screen the various candidate compressor types (reciprocating, scroll, and rotary), and (2) identify promising variable-speed heat pump system configurations for various applications and climates.

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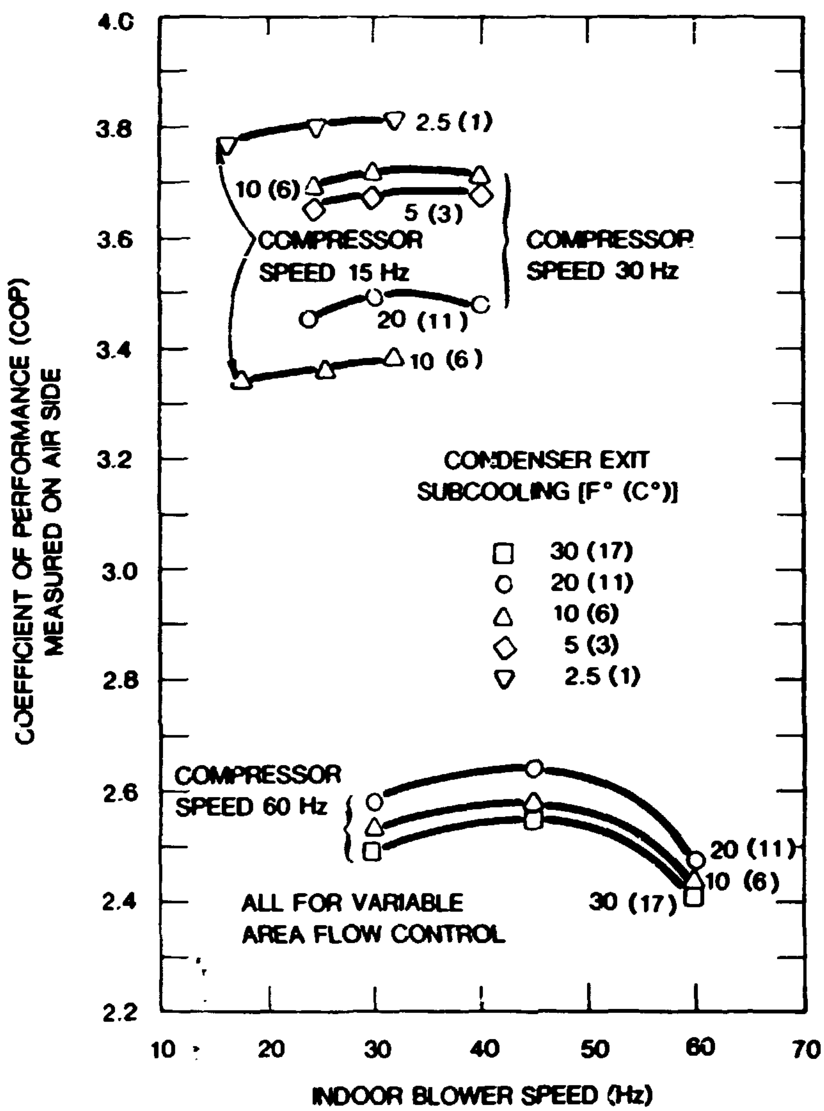

Fig 4.10. Modulating heat pump cooling performance.

4.2.3 Procedure for Optimizing Foundation Insulation

J. E. Christian

4.2.3.1 Introduction

A procedure that can be used to determine the optimum foundation insulation levels for new, low-rise residential buildings has been developed.[37] This procedure has been used to develop the recommended foundation insulation levels for ASHRAE Standard 90.2P.[38] Basement, crawl space, and slab-on-grade constructions are addressed, as well as floors above unheated spaces. The optimum foundation insulation levels are included for all locations in the United States.

More than 70% of the residential structures being built today have uninsulated foundations.[39] However, using this procedure, it can be shown that at least some foundation insulation is cost effective in most U.S. cities. The general methodology on which this optimizing procedure is based was established by ASHRAE Standards Project Committee (SPC) 90.2P for use in developing Standard 90.2P. The methodology couples energy load data with economic input to ensure that all the energy-conserving measures recommended in the standard are cost-effective.

This methodology has been used to demonstrate that ceiling insulation with a resistance to heat flow (R-value) of 5.3 K•m²/W (30°F•ft²•h/Btu), which is commonly installed in the field today, can be economically justified in many areas of the country. The same economic parameters selected for the above-grade envelope insulation optimization have been used to determine foundation insulation levels.

4.2.3.2 Foundation thermal performance

A number of available models were considered for use in generating the foundation energy load estimates. The model developed by Shipp[40] was selected for several reasons: (1) completeness of foundation types to choose from, (2) separate treatment of heating and cooling season performances, and (3) degree of validation against measured data.

A variety of conditioned basement walls are optimized for insulation levels and placement. The variations considered are "deep" and "shallow depth" below grade, concrete and masonry and permanent wood foundation (PWF) construction, uniform 1.2- and 2.4-m (4- and 8-ft) insulation coverage, and foam board and fiberglass batt insulation systems. The variations in unvented crawl space consist of concrete and masonry and PWF constructions and foam board and batt insulation systems. The slab-on-grade optimization is based on edge insulation extending a vertical depth of 0.6 and 1.2 m (2 and 4 ft) along the outside of the foundation stem wall. The final insulation configuration optimized is in floors over unconditioned space.

The installed cost data for the foundation insulation systems were developed by the National Association of Home Builders Research Foundation[41] and Dow Chemical U.S.A.[42] and represented the costs to the home buyer. The cost data were based on material and labor costs, and both subcontractor and builder markups were included to account for indirect charges, overhead, and profit. Both markups were assumed to be approximately 30%. The cost data were intended to be representative of national averages.

Using Shipp's model, a data base of foundation loads was produced. The foundation loads represented the heat loss or heat gain that contributed to the annual heating or cooling demand on the building's HVAC system. From this heating and cooling loads data base, delta loads were generated for each incremental insulation level. The delta loads represented the incremental reductions in the overall foundation energy load resulting from the incremental increase in the insulation level. The incremental delta loads for each insulation level were then plotted vs the appropriate parameter (i.e., heating degree days or cooling degree hours) for five climates; then, a linear-least-squares fit was calculated. The slopes of the lines which best fit the data are in units of Btu per heating degree days base 18.3°C (65°F) per linear foot and Btu per cooling degree hour base 23.3°C (74°F) per linear foot. To see how well these regression coefficients could reproduce the result from Shipp's model, a comparison was made and correlation coefficients (R^2 values) were calculated to estimate the degree of fit. The R^2 values for the heating loads were generally always above 0.87. This indicated that fit was good, given that the closer an R^2 value is to 1.00, the better the fit. However, the fit for the cooling loads was not as satisfactory. The values ranged from 0.53 to 0.98.

4.2.3.3 Procedure for developing the foundation insulation optimization curves

The installed costs and foundation energy loads for the incremental insulation levels were used in conjunction with other economic parameters to determine the optimum foundation insulation levels. It was assumed that if the incremental cost associated with a given insulation level was less than or equal to the corresponding energy savings on a net-present-worth basis, the insulation level was justified. The specific equation used in the analysis and the values selected for the economic parameters are shown below:

$$NPV = \frac{B_h \cdot HDD}{AFUE} \cdot P_h \cdot S_h + \frac{B_c \cdot CDH}{SEER} \cdot P_c \cdot S_c - FC \cdot S_m \tag{1}$$

where

NPV = net present value, 0;
B_h = regression coefficient for heating;
HDD = heating degree days base of 18.3°C (65°F);
$AFUE$ = annual fuel utilization efficiency, 68%;
P_h = price of heating fuel, \$5.313/GJ (\$0.561 per therm) of gas;
S_h = economic scalar factor for heating, 22.1;
B_c = regression coefficient for cooling;
CDH = cooling degree hours base of 23.3°C (74°F);
$SEER$ = seasonal energy efficiency ratio, 6.55;
P_c = price of electricity for cooling, \$0.0784/kWh;
S_c = economic scalar factor for cooling, 17.7;
FC = first cost for materials;
S_m = economic scalar factor for materials, 0.931.

The scalar factors, S_h, S_c, and S_m, are determined by the method of economic analysis selected. This study was based on a 30-year life cycle cost analyses. Scalars S_h and S_c are the modified present worth factors corresponding to the study period, discount rate, and energy price escalation factors for the types of energy used.[43] Scalar S_m is the ratio of the down payment and the current value of all mortgage payments (adjusted for income tax savings) to the first cost of the modification to which these payments apply.

After the most cost-effective insulation levels were identified for a given foundation insulation configuration, the curves corresponding to the given insulation levels were plotted. Using Eq. 1, NPV was set at zero, which meant that the energy savings equaled the modification cost. The series of these lines on a CDH vs HDD plot defines the areas where each level of insulation is recommended. Hence, the use of these plots along with the annual CDH and HDD values for any particular climate can be used to select a near optimum insulation level.

4.2.3.4 Discussion of the foundation insulation optimization curves

A couple of the foundation insulation optimization curves for the foundation constructions and insulation configurations considered are shown in Figs. 4.11 and 4.12. The major assumptions for each plot are listed in the upper right corner of each figure. Cities located directly on the lines in each figure represent areas where the heating and cooling energy savings exactly equal the incremental cost of the added insulation. For locations to the right of a given line, the combined energy savings exceed the incremental cost, but the savings are not great enough to justify the added cost of the next most cost-effective insulation level.

Figure 4.11 shows the optimum insulation levels for slabs-on-grade. The cost data represent extruded polystyrene foam insulation installed on the exterior and include the cost of a cementitious protective covering. Figure 4.11 illustrates that at least some slab edge insulation is cost effective for most climates.

Some unexpected developments were observed. Phoenix and Houston have the same optimum insulation level as Chicago, that is, R-0.70 (R-4) installed vertically on the exterior for a total

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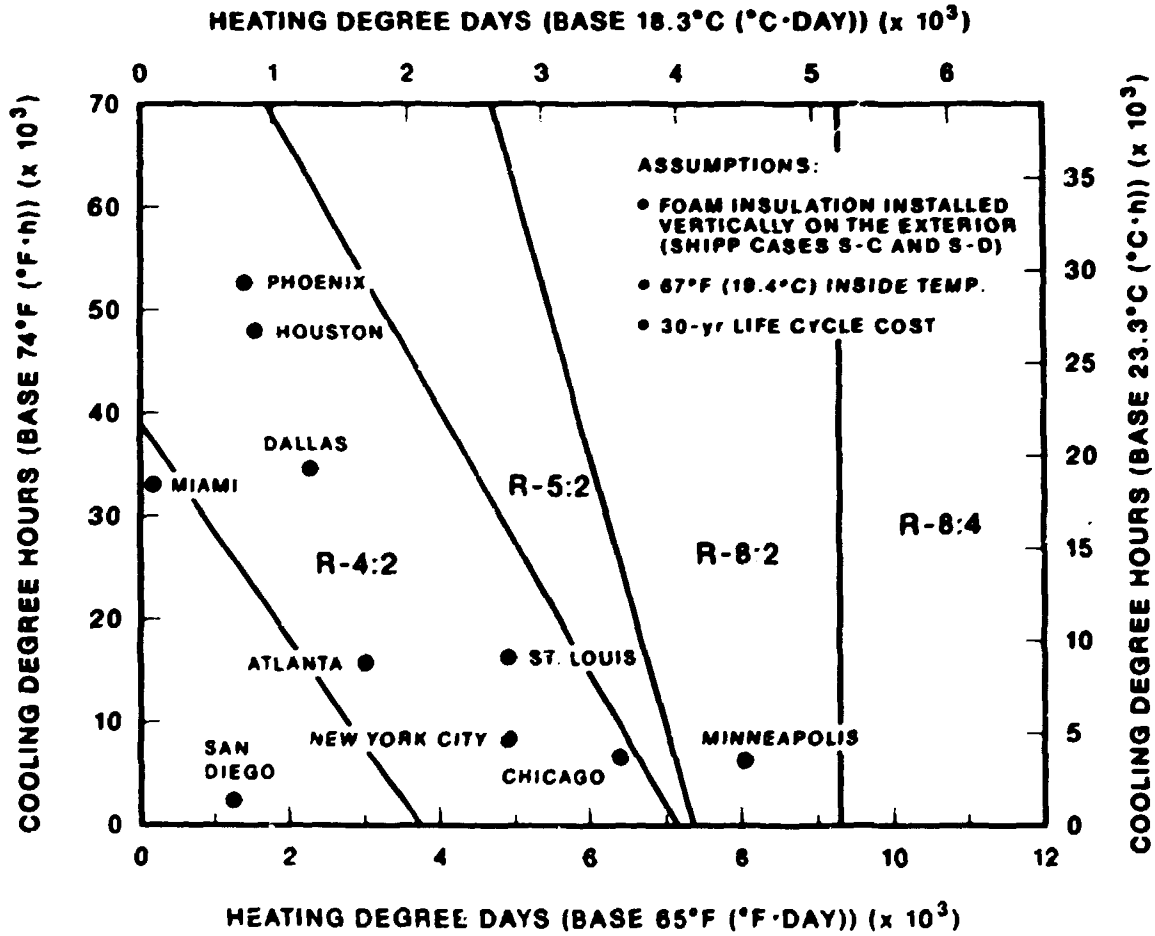

Fig. 4.11. Optimum foam board insulation levels for slabs-on-grade. In R-4:2, R-5:2, etc., the first number represents the insulating value, and the second number gives vertical depth (ft) on the slab edge.

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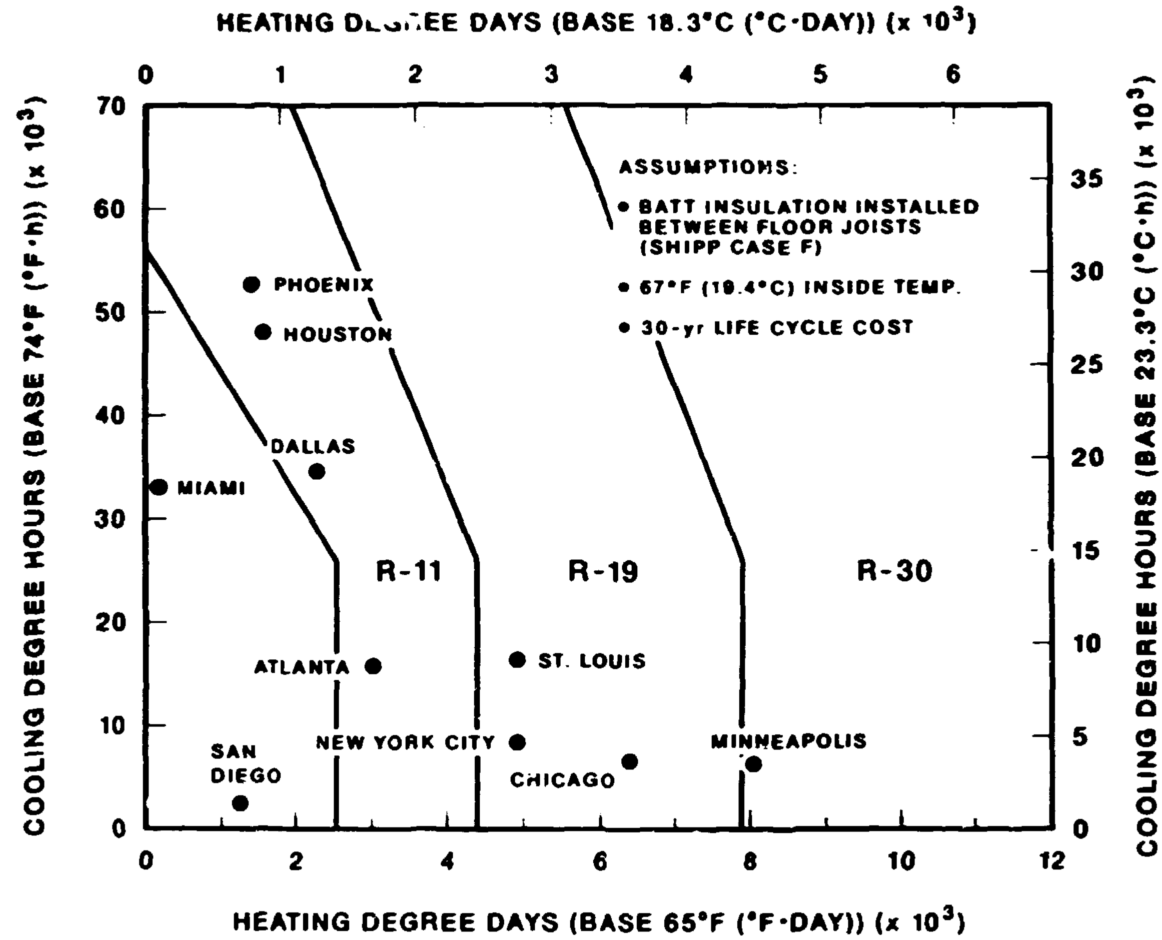

Fig. 4.12. Optimum batt insulation levels for floors over unheated spaces.

distance of 0.6 m (2 ft). According to current building practice, little or no slab perimeter insulation is installed in Phoenix and Houston; in Chicago, levels greater than that deemed cost effective in this study are installed in many cases. Likewise, in Minneapolis, insulation levels greater than R-1.41 (R-8) are typically used. Hence, in several cases, the calculated optimum insulation levels were inconsistent with current established practice. One possible explanation was that in the slab-on-grade model, the benefit of adding insulation was overestimated for the cooling season and underestimated for the heating season. Work needs to be done to further explore this question.

Figure 4.12 shows the optimum insulation levels for floors over unheated spaces, such as unheated basements, vented crawl spaces, and garages. The curves for the floor insulation levels differ in appearance from those for the other foundation constructions and insulation configurations. A unique approach was introduced to resolve a specific dilemma that developed. For climates with <15,000 CDH base of 23.3°C (27,000 CDH base of 74°F), the cooling loads were greater at higher insulation levels.

This dilemma was resolved by ignoring the cooling loads in climates with <15,000 CDH base of 23.3°C (27,000 CDH base of 74°F). As a result, the curves are vertical for those locations. For cities that experience >15,000 CDH base of 23.3°C (27,000 CDH base of 74°F), the cooling season performance was reintroduced. The resulting curves indicate that floor insulation reduced the annual cooling loads. However, for climates with <15,000 CDH base of 23.3°C (27,000 CDH base of 74°F), the cooling "penalty" for insulating the floor was ignored. As shown in Fig. 4.13, in climates with >15,000 CDH, adding R-1.94 (R-11) batt insulation to the floor results in reduced loads for the heating season which are on the average about eight times greater than the cooling "penalty."

4.2.3.5 Conclusion

The section describes a procedure for determining the optimum foundation insulation levels for most typical new low-rise residential buildings, based on the best available validated thermal performance models.[37] It is concluded that additional work on crawl-space and slab thermal performance prediction techniques is warranted in the near future.

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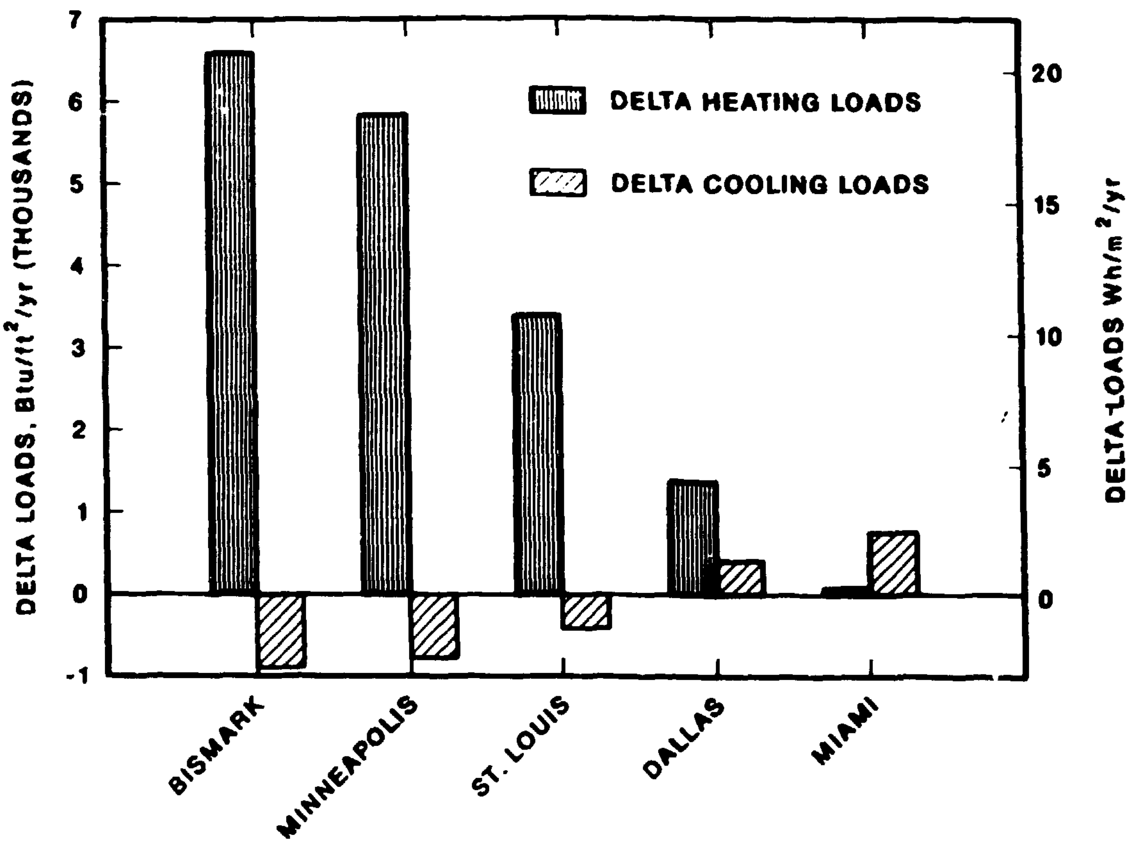

Fig. 4.13. Delta heating and cooling loads for five cities for the first increment of R-11 insulation in the floor.

4.2.4 Determination of Thermal Resistance of Building Roofs from In Situ Data

G. E. Courville

It is now common practice to define the field-derived one-dimensional thermal resistance of building envelope components by the equation

$$R = \frac{\sum_{N}^{n-1} (\Delta T)_n}{\sum_{N}^{n-1} q_n} \, , \tag{2}$$

where ΔT_L is the temperature difference across the component and q_n is the heat transfer per unit area. The summation is over N equal size time intervals (the time intervals are usually 1 h and N is usually an integral number of 24-h periods). where N is large enough for the ratio to converge to a unique value. Convergence depends upon the thermal storage of the element; for lightweight insulated roofs, this is less than 72 h. For normal weight concrete walls backed by insulation, the convergence time can be considerably longer.

Recent work on the Roof Thermal Research Apparatus (RTRA) with several insulated roof systems has substantiated the usefulness of this technique and has also shown its shortcomings. An alternate technique has been proposed.

In the RTRA, test specimens are installed in 1.2 × 2.4 m (4 × 8 ft) frames and mounted in the roof of the RTRA where their exteriors are exposed to the local weather and their interiors are held at room conditions. Specimens are instrumented according to the needs of a particular experiment. One such experiment is shown in Fig. 4.14. Here, the sensors provide temperatures on either side of a roof insulation board and the heat flux through the board. This is adequate to solve Eq. 2. A typical output curve is shown in Fig. 4.15 in which the R-value, determined from Eq. 2 for a week in January 1986, is continuously updated each hour over the entire 7-day period. For weather conditions in which the heat flow is nearly always out of the building, one can show that the field R-value should converge to the steady state R-value provided the mean temperature does not change significantly over the measurement period.

There are two principal shortcomings of the technique for measuring thermal resistance represented in Eq. 2. First, the ratio from Eq. 2 becomes erratic when q_n is near zero because even small instrument error can dramatically alter the result; and, second, the mean temperature at which the R-value is to be reported is ambiguous because the temperature across the specimen is continuously changing. The former causes problems during mild weather conditions, and the latter makes it difficult to compare results obtained under different conditions.

ORNL has overcome these shortcomings by adopting the "inverse heat transfer" method developed by project consultant Prof. James V. Beck of Michigan State University.[44] In this method, labeled PROPOR after the computer code, the fundamental heat transfer equations are structured so that experimentally determined temperatures and heat flows are inputs and the thermal properties of the system, i.e., the thermal conductivity and the thermal diffusivity, are the outputs. The technique is numerical and has been simplified to fit onto a personal computer.

The first problem above has been eliminated because the artifact of dividing by zero has been removed. The second is handled in PROPOR by assuming that the thermal properties are functions

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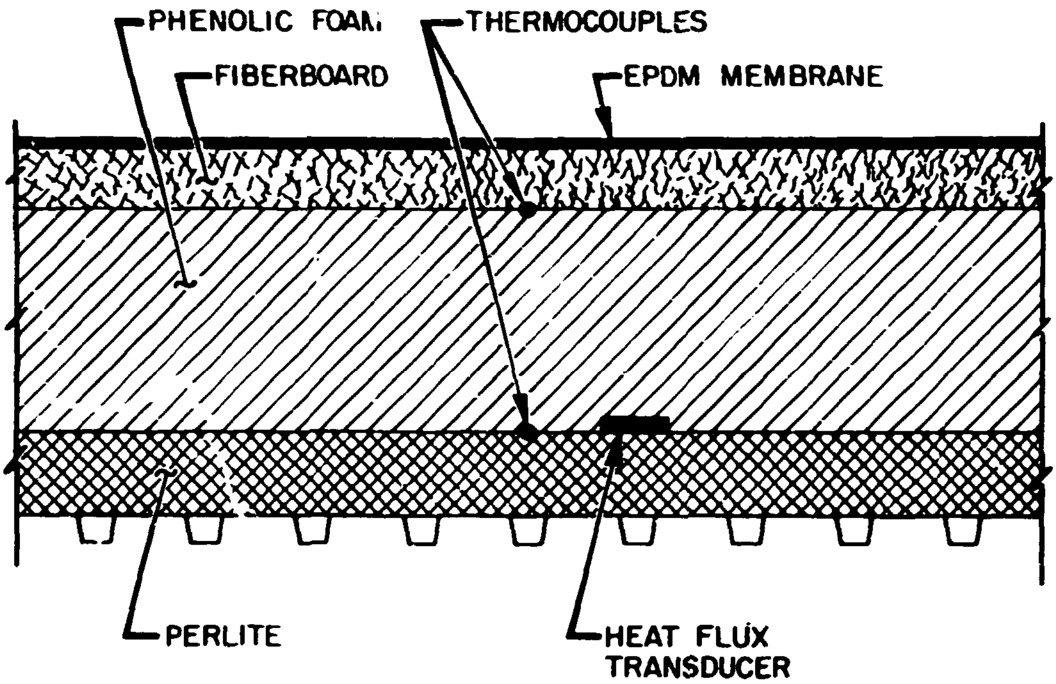

Fig. 4.14. Roof cross-section showing sensor placement.

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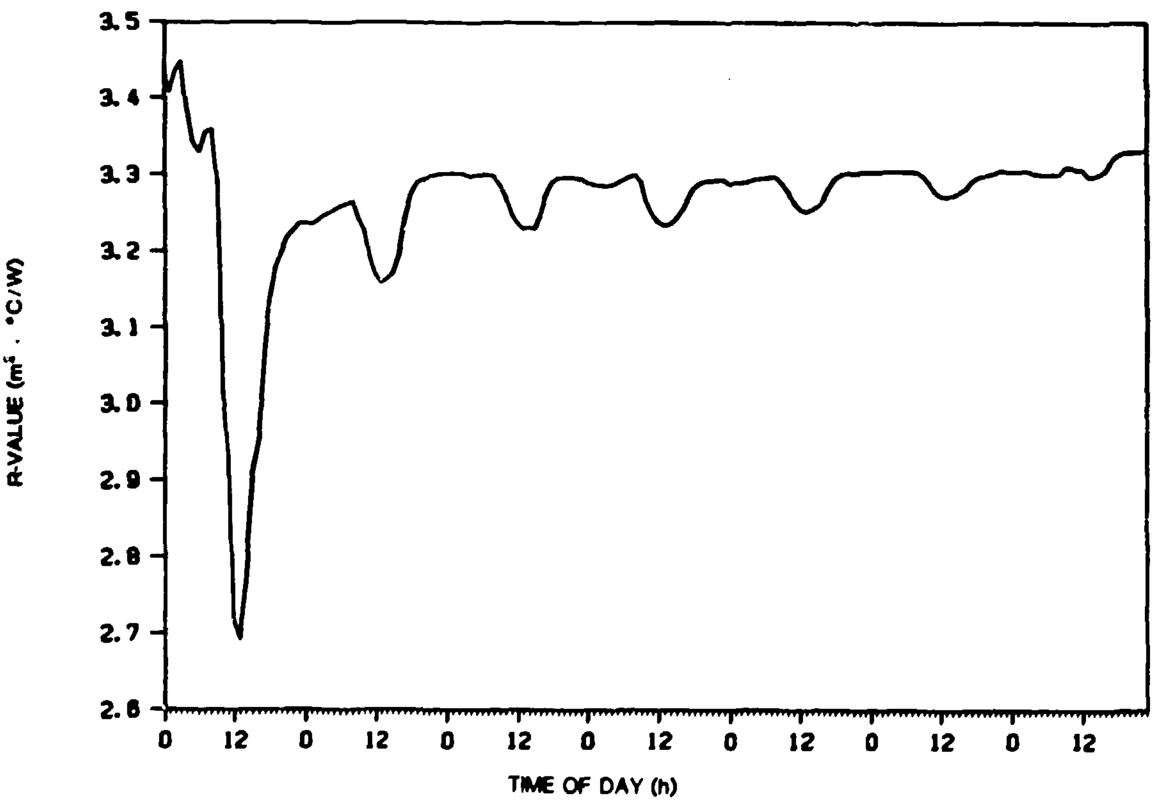

Fig. 4.15. Field-derived roof R-value using Eq. 2.

of temperature (usually linear) and solving for the coefficients. To illustrate the superiority of this new procedure, compare the results in Fig. 4.16 with those in Fig. 4.17. Both are plots of the long-term behavior of the R-value of a 5-cm (2-in.) phenolic foam insulation board mounted under a waterproofing membrane on the RTRA. Each data point labeled R(field) in Fig. 4.16 is the R-value taken from Eq. 2 for $N = 168$ h, i.e., the R-value at the right intercept from a large number of curves similar to that in Fig. 4.15. The data points in Fig. 4.16 are for the same time periods using the PROPOR program. In both figures, the solid curve is the R-value for the same sample as determined at ORNL under limited steady state conditions. Under the conditions of the experiment, one expects the field data to agree with the laboratory data; from other sources[45] we know that the R-value curve at temperatures below those measured in the laboratory tends to flatten out such as the PROPOR data suggest. Examination of the results has shown that the fluctuations in the field data in Fig. 4.16 are a result of the difficulty in using Eq. 2 when the average heat transfer is near zero; the disagreement between the field data and the lab data at higher temperature is a consequence of the ambiguity in specifying the mean temperature assigned to each field data point. In each instance that the methods have been compared, the PROPOR approach for determining the R-value of roof specimens has proved to be equal or better than the averaging technique. Following some additional applications in FY 1987 to different types of building envelope systems, the PROPOR technique will be submitted to the American Society for Testing and Materials (ASTM) as a suggested technique for field measurement of the thermal properties of insulated envelope systems.

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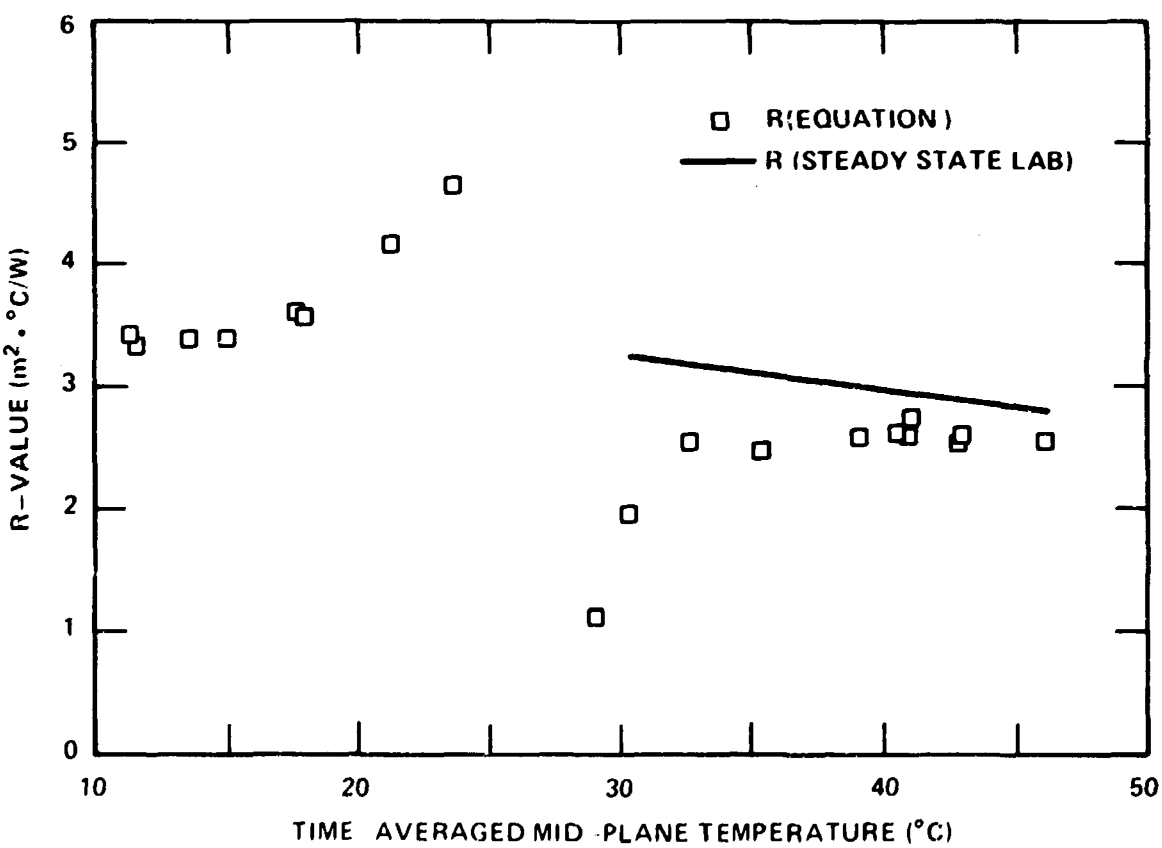

Fig. 4.16. Weekly average R-values from Eq. 2 plotted against weekly mean temperature.

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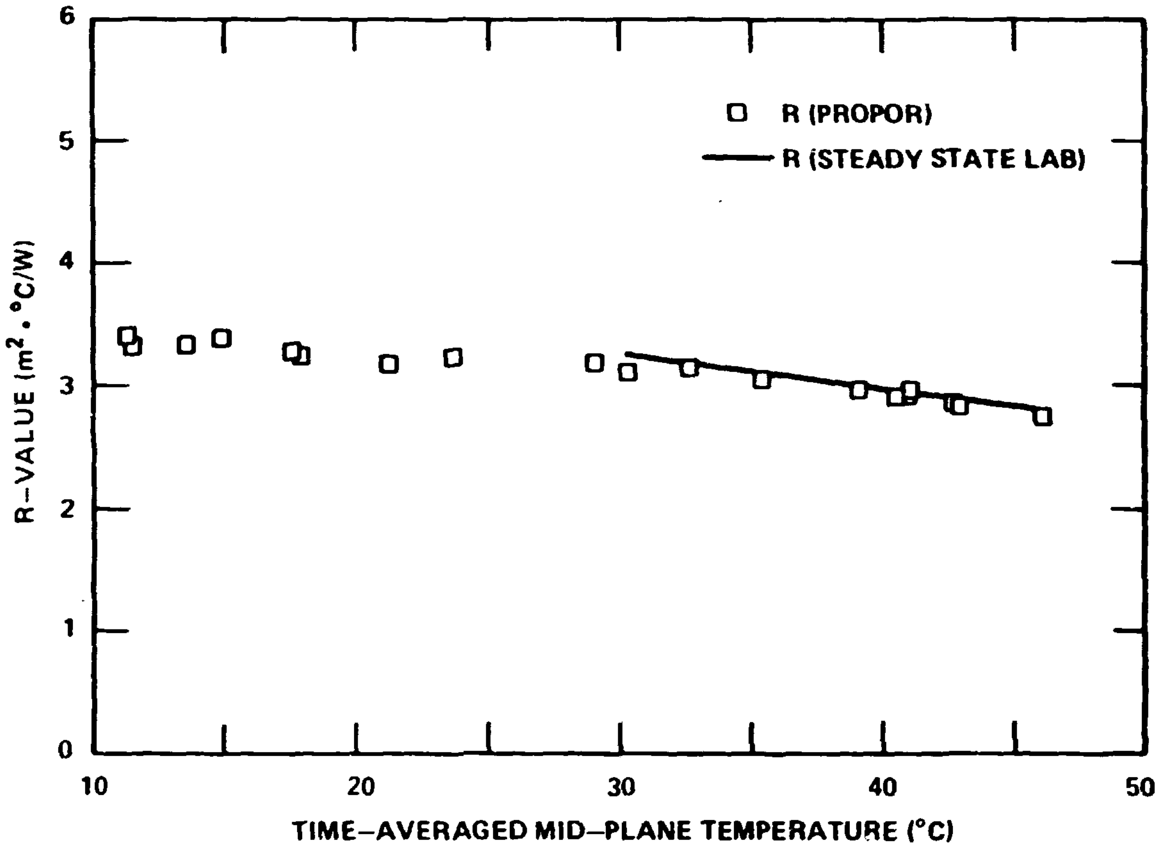

Fig. 4.17. R-value vs temperature determined using the inverse heat transfer method.

4.2.5 Field Measurement of Single-Family Retrofit Performance in Wisconsin

L. N. McCold M. P. Ternes

As part of the Building Energy Retrofit Research Program, ORNL participated in a cooperative project to measure the effectiveness of an audit for selecting retrofits in the Low-Income WAP. The usual approach in the WAP is to spend up to a designated maximum amount on each house to install certain standard retrofits (e.g., caulking and weatherstripping, ceiling insulation, or storm windows). The audit for this study includes a larger number of retrofits. In addition to the usual and not so usual (e.g., exterior basement wall insulation) shell retrofits, it includes a number of retrofits to increase heating system efficiency. The audit provides estimates of costs and savings for each retrofit based on the characteristics of each individual house and the interactions between the retrofits. To achieve the greatest cost effectiveness (within other constraints), the retrofits that were performed were those which had the highest benefit-to-cost ratios for a group of houses.[46,47]

The study was a cooperative effort of a large number of organizations. The Alliance to Save Energy (ASE) initiated the project by bringing together the principal participants. ASE had developed mechanical retrofit programs for oil and gas furnaces and wished to see them tested in the WAP. The state of Wisconsin funded the Wisconsin Energy Conservation Corporation (WECC) to implement the test. ORNL developed the audit, designed the study, and executed the analysis. Three gas and electric utilities provided funds to purchase and install meters used for the field measurements.

To provide results in a timely fashion, new field measurement and analysis methods were developed. Heating system gas consumption was measured at weekly intervals. Preretrofit energy consumption measurements began in October or early November and ended in January or February before the retrofits were performed. Postretrofit measurements were begun upon completion of the retrofits and ended in May. Regression analysis of preretrofit and postretrofit data and historical weather data were used to estimate normalized annual energy savings.

The study results show that use of the audit led to larger average energy savings at a lower average cost. In 1983, Wisconsin's WAP spent about $2200 per weatherized house and saved an average of 84–137 GJ/year (80–130 therms/year). In this study, about $1600 per house was spent for retrofit and audit costs. Average measured savings were 17.3 GJ/year (164 therms/year) [standard error: 6.2 GJ/year (59 therms/year)]. An additional 4.0 GJ/year (38 therms/year) average savings per house was estimated (but not measured) as a result of eliminating gas pilots in furnaces, yielding total savings of 21.3 GJ/year (202 therms/year).

Examination of aggregate results shows that an audit is clearly beneficial to the WAP. Comparison of energy savings, as measured and predicted by the audit, gives a clearer picture of the strengths and weaknesses of the audit. Figure 4.18 shows comparisons of predicted and measured energy savings for individual houses and notes the principal retrofits of each house. The houses appear to fall into three groups: those that had an old furnace replaced by a new condensing furnace, those that had wall insulation installed, and those that had no major retrofits installed. [Major retrofits are those that have predicted annual savings of 10.6 GJ/year (100 therms/year) or more.]

The predicted and measured savings of the three groups are listed in Table 4.1. As a group, the houses that had a new condensing furnace installed did best, achieving over 102% of the predicted savings; the difference is easily within the bounds of measurement error. The average measured energy savings of the houses that received insulation was only about 70% of the predicted savings. The houses with no major retrofits showed no significant change in energy consumption.

Figure 4.18 shows that despite using groups of similarly treated houses, there is a significant scatter. Even the houses that received condensing furnaces and, as a group, achieved about the predicted amount of energy savings show a wide scatter about the predicted values of energy savings. Two of these houses had measured savings that were significantly less than predicted ($p < 0.05$), and one had significantly larger than predicted savings. This amount of scatter shows that the audit does not yet account for all of the factors that influence energy savings appreciably. A leading contender for the cause of such discrepancies is occupant behavior.

Submetered data, including indoor temperature data, were collected in a subset of the homes to study occupant-behavior-related issues. The energy savings predictions noted above were made assuming that the indoor temperature before and after the retrofit was constant and that the house had a 18.3°C (65°F) balance point. Indoor temperature data collected in the sub-metered homes indicated that the postretrofit temperatures were higher than the preretrofit temperatures in many cases. In addition, house balance point temperatures, which are affected in part by the occupant's regulation of the heating system equipment, ranged from 7 to 24°C (45 to 75°F). The difference

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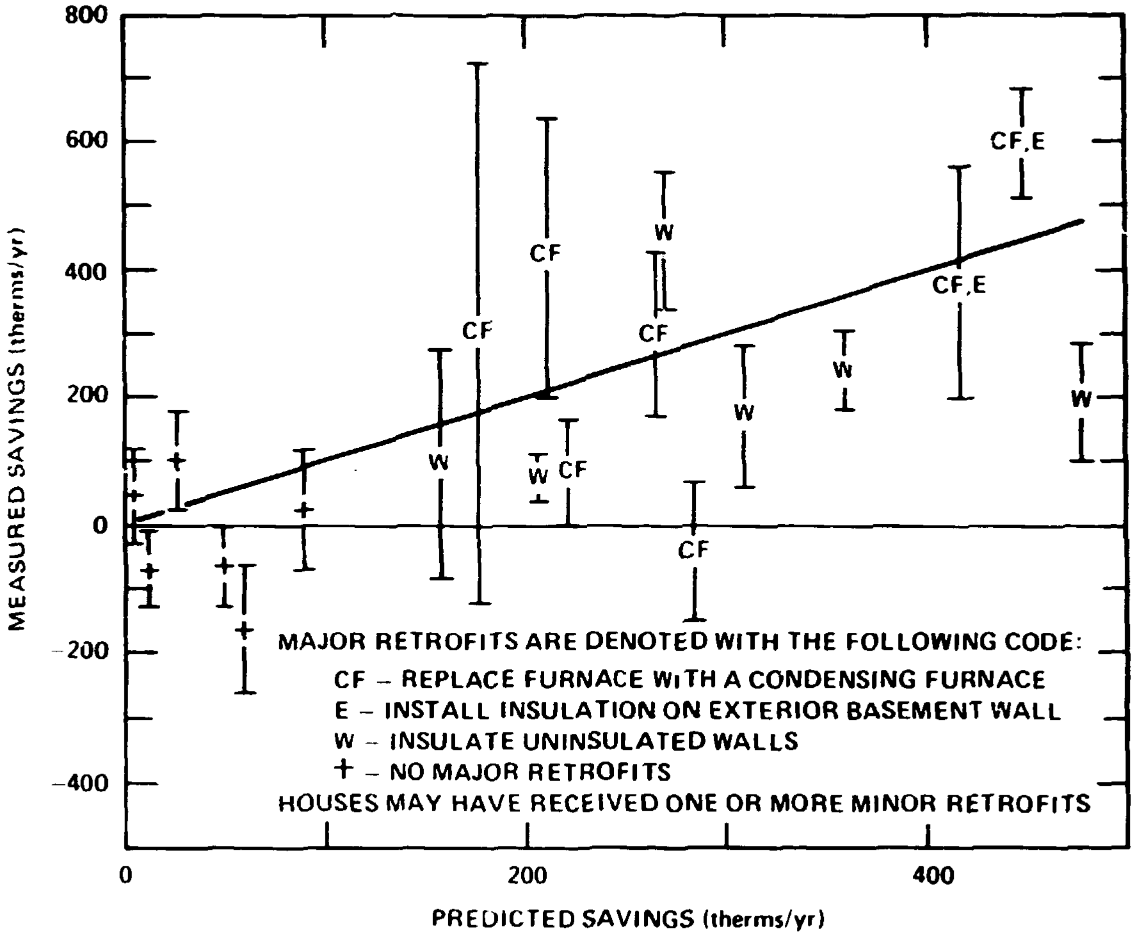

Fig 4.18. Comparison of predicted and measured energy savings of individual houses. Vertical lines indicate the 90% confidence intervals of measured savings.

Table 4.1. Energy savings and predictions by subgroups of audit group houses

Major retrofit	No. of houses	Average predicted savings (GJ/year)	Average measured savings (GJ/year)	Standard error
Wall insulation	6	31.4	21.9	2.7
Condensing furnace	7	30.5	31.2	4.7
Less than 10.6 GJ/year predicted	7	3.7	−0.7	2.0

between predicted and measured energy savings was reduced between 20% and 50% in five audited and control homes when the indoor temperature was included in the analysis and prediction assumptions were followed; the difference increased significantly in only one case.

Additional analysis of the submetered data indicated that changes in occupant behavior following retrofit installation were similar to behavior changes made by occupants living in the control homes. Thermostat set-point patterns (night setback, etc.) remained unchanged in all the submetered houses. The temperature measured at the thermostat generally either increased with increasing outdoor temperature or remained the same. Postretrofit indoor temperatures increased in the audited and blower door houses by approximately the same amount as that in the control houses.

4.2.6 Athens Automation and Control Experiment

P. A. Gnadt	W. R. Nelson	R. A. Stevens
P. S. Hu	J. H. Reed	J. P. Stovall
K. F. McKinley*	D. T. Rizy	T. A. Vineyard

The Athens Automation and Control Experiment (AACE) has been discussed in previous Energy Division annual progress reports.[48–49] The AACE has integrated several automation methods into a single control system, is developing and testing control strategies, and will be evaluating the benefits of this integrated system. The experiment is being conducted with the collaboration of the Athens Utilities Board (AUB) in Athens, Tennessee, on their distribution system. During FY 1986, the AACE completed the first year of a two-year experimental period. The project accomplishments are described below in the three principal experimental areas being conducted: (1) voltage/reactive power control, (2) system reconfiguration, and (3) load control.

A unique method of measuring the impacts of control on the distribution system in the three experimental areas was perfected during the year. A high-speed data acquisition system capable of recording ten analog data channels at an aggregate rate of 10,000 samples per second has been used. The system is based upon a minicomputer and can be set up in the substation to monitor real power, reactive power, and voltage on each phase of a feeder (see Fig. 4.19). This high-speed data acquisition system (data logger) allows the monitoring of impacts from a control action on a millisecond time frame basis. By monitoring impacts on this time basis, the effects of capacitor switching, load-tap-changing, line switching, and load control have been delineated.

The voltage/reactive power control experiment has concentrated on determining the system response due to voltage control using the substation load-tap-changing transformer and reactive power control using capacitor banks. The change in real power flow has been found to be quite sensitive to changes in voltage. In general, the real power increased with capacitor switching in and decreased with capacitor switching out, which is contrary to traditional simulation models used by the industry. Figure 4.20 shows one such experiment in which switching in a capacitor bank resulted in an increase in real power. Conventionally, the utility industry uses a load model that is not sensitive to voltage to simulate the response of the distribution system to capacitor control and

*Baltimore Gas and Electric Company.

ORNL-PHOTO 3203-86

Fig. 4.19. High-speed data logger.

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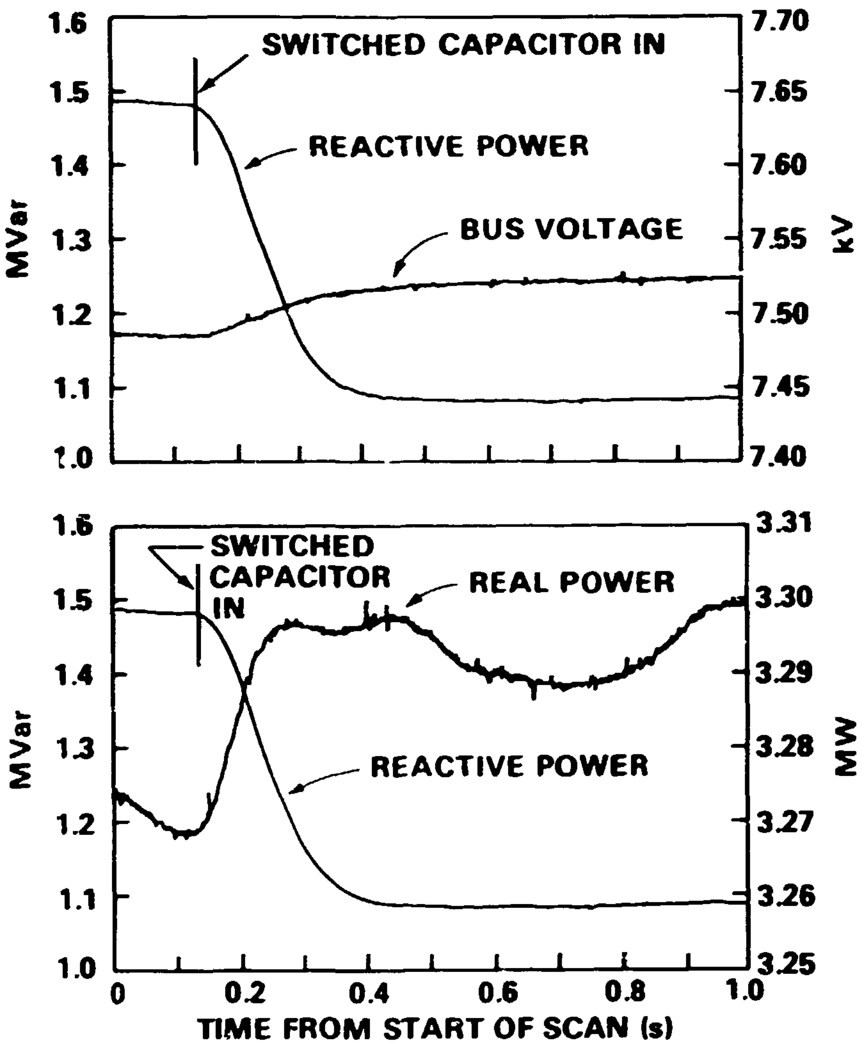

Fig. 4.20. Capacitor switching test.

other perturbations. Such a model would predict a decrease in real power because of a decrease in system losses. Load-tap-changing transformer control tests have further confirmed the sensitivity of the customer loads to voltage.

A procedure has been developed for automating the control of distribution feeder capacitors using the substation and feeder monitoring and control hardware system installed on the AUB distribution system. The purpose of the procedure is to control capacitors for power factor control. A computer program implementing the procedure has been written and is being tested on the AUB system. If successful, the use of this procedure could lower the cost of buying TVA power for the AUB system.

The system reconfiguration experiment has concentrated on determining the impact of transferring load between feeders. One such experiment is shown in Fig. 4.21. The analysis has determined that load sensitivity to voltage has a major impact on the AUB system response to "large" load transfers. A personal computer analysis tool called the System Reconfiguration and

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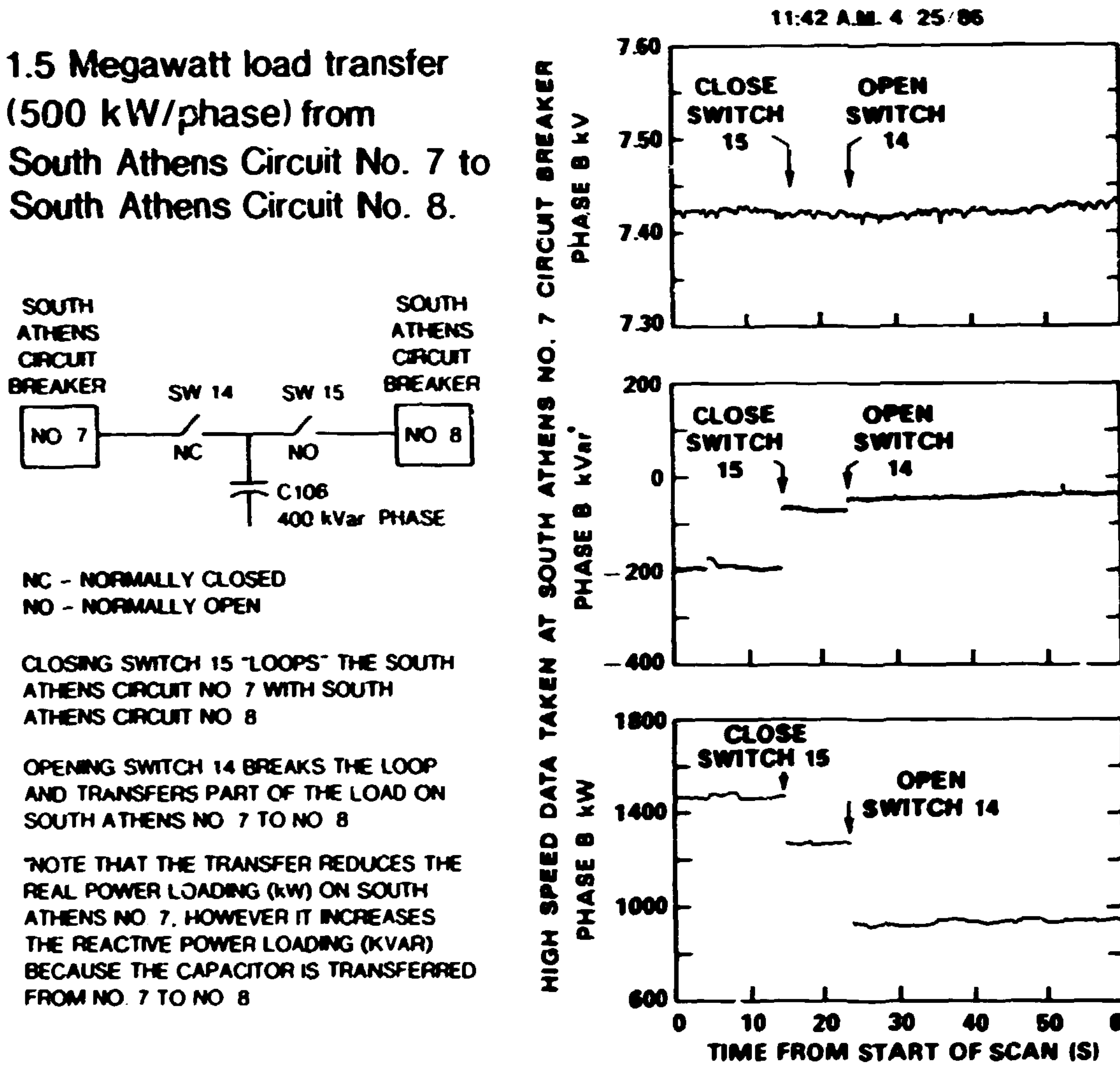

Fig. 4.21. Megawatt load transfer between circuits.

Analysis Program (SYSRAP) has been developed to simulate load transfers and capacitor switching. The program combines the features of power flow analysis and data base manipulation. This type of program does not exist in industry today. SYSRAP also allows the use of different load models that have increasing order of sensitivity to voltage. The program has been able to simulate fairly well feeder responses to capacitor switching and load transfers when conventional programs have not been adequate.

The load control experiment began during the summer of 1986 with the cycling of air conditioners. Water heater control and space heater control began in the fall of 1986. The impact of cycling air conditioners on a feeder was directly measured using the high-speed data acquisition system. Figure 4.22 shows the two-stage shedding used in the AACE communication system. Figure 4.23 clearly shows the inrush current caused by starting torque as compressors are restored in groups.

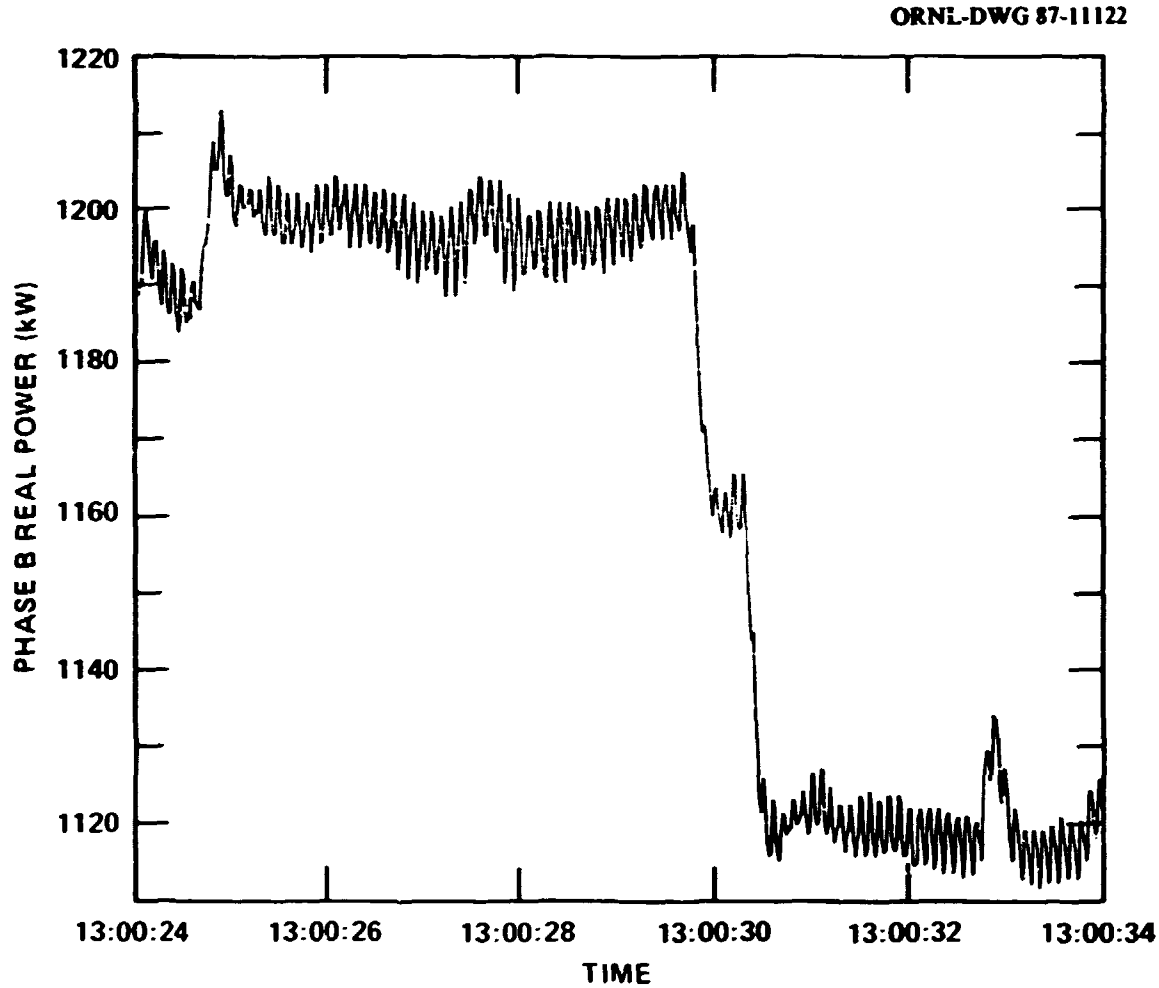

Fig. 4.22. Air-conditioner load-shed experiment.

In addition to TVA, which supplies power to AUB, and EPRI, participants in the Athens experiment include the Tennessee Valley Public Power Association, which represents major TVA users, and a utility advisory group composed of ten utility experts from across the United States.

The successful completion of experimentation with AACE will result in altered patterns of energy use, reduced daily operating costs, and reduced peak power demand. By giving utilities more knowledge about hour-to-hour loads, the power system can be operated closer to its current limitations and future utility system expansions can be deferred. This will result in major changes in the design and operation of utility companies nationwide.

4.2.7 Electromagnetic Pulse

P. R. Barnes T. L. Hudson* R. A. Stevens
P. A. Gnadt B. W. McConnell

The detonation of a nuclear weapon in or above the atmosphere would produce a strong electromagnetic pulse (EMP) with an electric field component on the order of tens of kilovolts per

*Engineering Division.

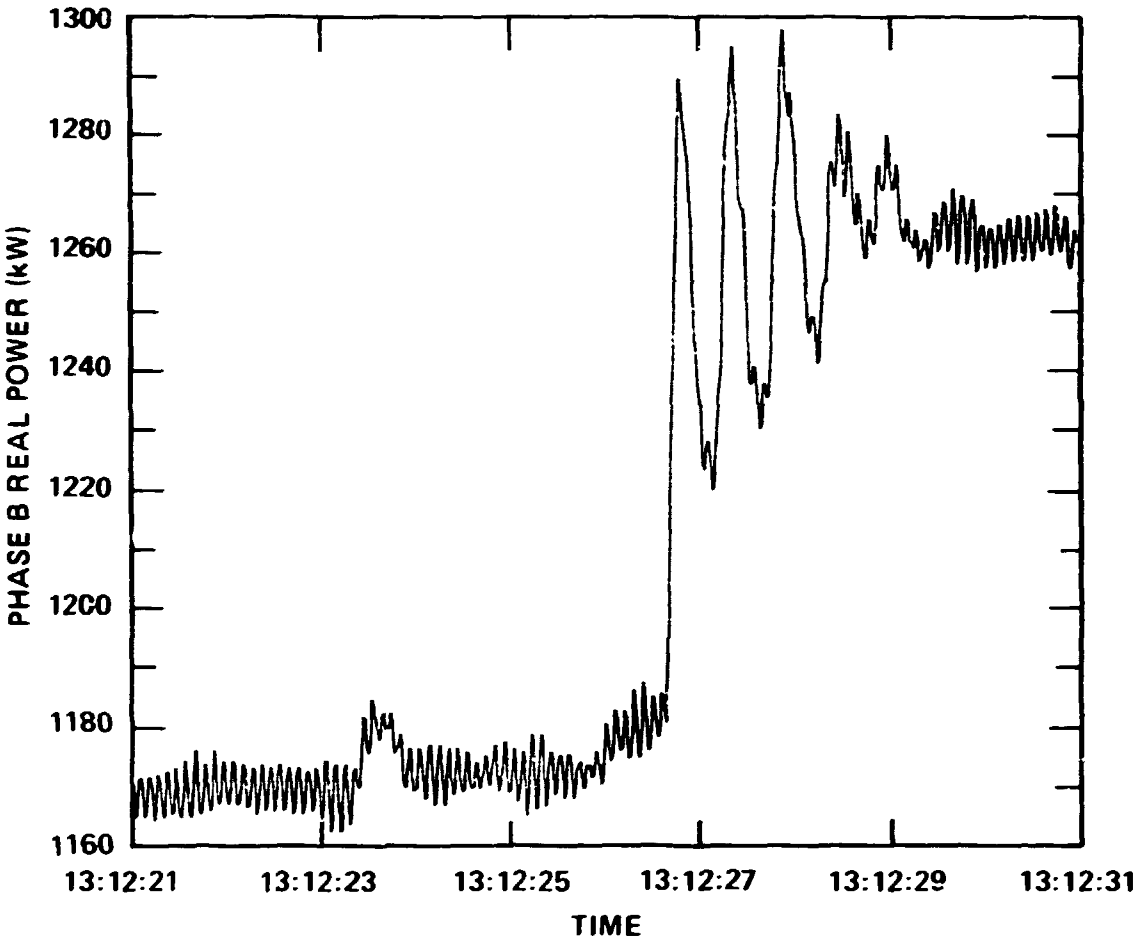

Fig. 4.23. Air-conditioner load restoration.

meter. If the detonation occurred in space, several hundred kilometers above the central United States, a single high-altitude burst could subject much of the continental United States to a strong EMP, as shown in Fig. 4.24 for a height of burst (HOB) at 100 km and 400 km, respectively. There is concern that one or more EMPs resulting from high-altitude detonations could disrupt electric power systems and cause massive power outages. To address this concern, the DOE Office of Energy Storage and Distribution has formulated a research program to develop technologies and systems required to assess and reduce the impact of EMP on electric power systems.[50] ORNL has the lead role in managing the research activities and providing technical guidance to subcontractors conducting studies on the impacts of EMP on power systems.

The primary goals of this program are to assess the effects of EMP on electric power systems and, if necessary, improve power systems reliability when subjected to EMP. A secondary goal is to enhance the reliability of the power system during peacetime disturbances such as fast transients, geomagnetic storms, and lightning.

The first task performed under this program was to review prior studies and scope the problem.[51,52] Other tasks performed during the first phase of the program were EMP coupling studies in 1983.[53,54] This work was concentrated on the early-time response of transmission and distribution lines using unclassified EMP waveforms. Studies were also conducted on characterizing

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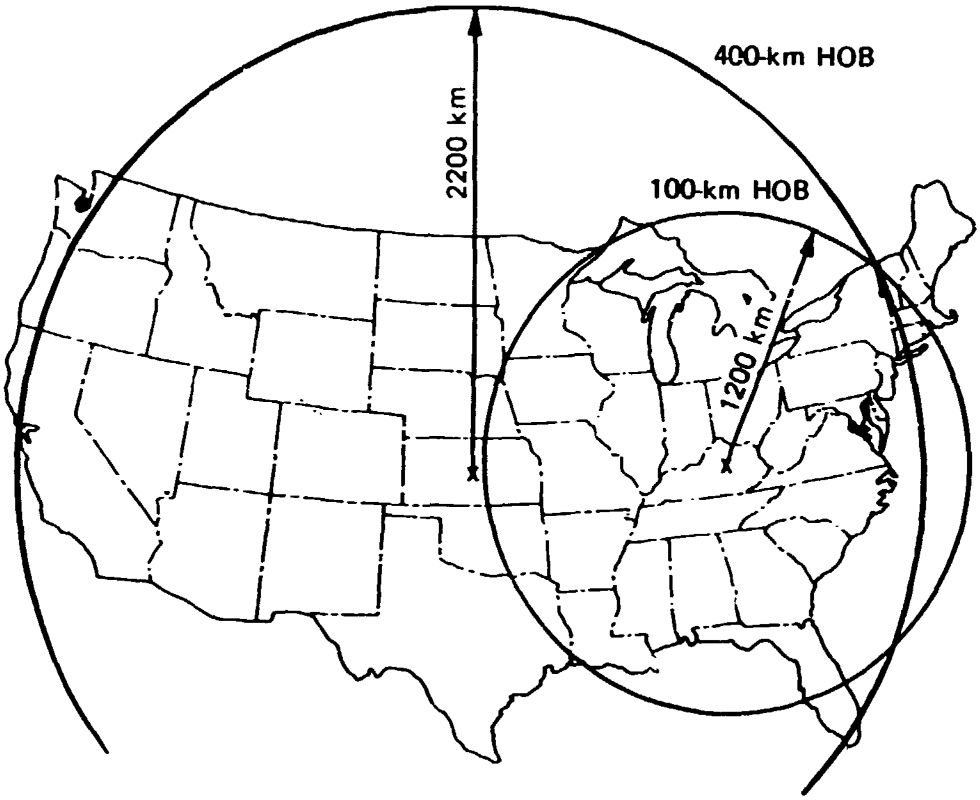

Fig. 4.24. Areas of coverage of EMP from high-altitude detonations.

the response of a simple distribution system, modeling EMP-induced dielectric stresses, and theoretically investigating the impact of corona on EMP-induced power line response. The results of this early scoping research have been useful in defining the balance of the research efforts.

The major research effort of this program is the power systems assessment, which is subcontracted to the Advanced Systems Technology Division of the Westinghouse Electric Corporation. Westinghouse is assisted in this work by LuTech, Inc., Rockwell International, and Arizona Public Service. The research is divided into three major phases.

Phase I of this activity began in FY 1984 and resulted in the development of an EMP assessment methodology for electric power systems. The second phase of the project was divided into two sub-phases. Phase IIA, which was conducted in FY 1985, produced a set of computer programs that applied the assessment methodology of Phase I and a data base for use in the later assessments. During Phase IIB, which began in FY 1986 and is expected to be completed in FY 1987, a preliminary assessment of the Arizona Public Service system is being conducted. Phase III of the project, scheduled for FY 1987-88, will perform a series of more detailed assessments. A study to develop protection techniques is also included in the latter part of Phase III.

As a parallel endeavor, a research project to determine the effects of steep-front, short-duration impulse on insulation systems used in power system apparatus is being conducted by the McGraw-Edison Division of Cooper Industries. The project has examined the known impact and sources of steep-front, short-duration impulses and has defined an experimental program. Current efforts include experimental investigations of several insulation systems using a range of voltages and impulse shapes and the development of predictive models for insulation behavior.

In addition to research efforts directed at power systems, the program has undertaken a series of projects aimed at developing concepts and equipment for simulating the EMP environment.[55–57] A series of conceptual studies has been completed, and a 2.2-MV EMP pulser at Maxwell Labs in San Diego, California, has been modified to allow direct pulse injection onto electrical apparatus and insulation system modules. This pulser is being used in a series of tests that are being conducted by Westinghouse and McGraw-Edison as part of their research efforts. Further component and subsystem tests are planned. McGraw-Edison will also be conducting insulation experiments using existing McGraw-Edison facilities and a tunable, portable 200-kV EMP pulser that is on loan from the Defense Nuclear Agency (DNA).

A set of special research activities included in the program to support the major research projects is designed to address unanticipated or critical questions that arise during the course of the investigations. A project of this type that has been conducted recently is corona experimentation performed by LuTech with assistance from the EG&G and BDM Corporations and DNA. This project was designed to experimentally determine the effects of corona on EMP-induced surges and to gather data for validating various models of the phenomena. Other projects are planned to develop protective hardware if the preliminary assessments indicate a need and to develop operating and control strategies that could limit damage and speed recovery.

4.2.7.1 Major accomplishments

The initial studies determined "worst case" EMP-induced surges in overhead electric power system transmission and distribution lines using unclassified EMP environment information. Also, methods of simulating the EMP-induced surges for testing equipment were studied. These early studies pointed to the need to obtain experimental data and to use a more realistic EMP environment for assessing electric power systems over a large area. An EMP assessment methodology for electric power systems has been developed by Westinghouse.[58] The methodology includes relatively simple unclassified EMP environment models. The assessment methodology extends EMP coupling models to the large transmission and distribution network associated with electric power systems and describes a method to determine the impact of EMP on the overall power system.

A preliminary investigation of the impact of steep-front, short-duration impulse on a selected number of insulation systems used in the electric power systems apparatus has been completed.[59] The results of this research indicate that, in addition to EMP, several sources of steep-front, short-duration impulse exist on power systems and that some anomalous failures of power delivery apparatus, such as transformers, motors, and cables, may be attributed to steep-front, short-duration impulse.

The second phase of the McGraw-Edison insulation study is under way. Preliminary results using low-voltage, steep-front, short-duration impulses indicate that this type of impulse produces very nonuniform voltage distributions in transformers. These results, the basic insulation strength of the system under a steep-front stress, and the calculated EMP voltage level imply that there is a high probability of insulation failure under EMP-induced surges.

An experiment to investigate the effects of corona on the coupling of EMP to conductors has been performed. Preliminary analyses of the data collected in this experiment were reported at the

1986 NEM conference.[60] The results indicate the following: (1) corona is present under EMP-induced surge conditions, (2) the surge rise time is increased, (3) the effective rate of rise is decreased, (4) some reduction of the peak voltage can be expected, and (5) the probability of power line flashover may be increased.

To obtain more realistic information on the EMP environment for assessments, Mission Research Corporation has used unclassified weapon parameters with EMP environment calculation codes to determine a nominal set of EMP waveforms.[61] This effort was jointly sponsored by DOE and DNA.

The development of an unclassified EMP environment by the Mission Research Corporation has greatly enhanced the ability of this research program to correctly assess the impact of EMP on power systems.

4.2.7.2 Conclusions

The assessment of the impact of EMP on electric power systems is a very complicated undertaking and presents a problem that cannot be completely solved by either experimental or theoretical methods. The program has determined that (1) a realistic, large-area EMP environment for high-altitude detonations is needed for a complete assessment, (2) EMP can induce power line surges with over 1-MV peak voltage and a variety of pulse shapes, (3) steep-front, short-duration impulse may have a high probability of damaging insulation systems, (4) corona is an important factor, and (5) the communications and control systems using solid state components may be damaged.

4.2.8 Advanced Chemical Heat Pump Working Fluids

S. I. Kaplan

Advanced high-temperature working fluid pairs for CHPs have been developed and characterized by Desert Research Institute (University of Nevada)[62] and by Energy Concepts Company.[63] Both organizations were instructed to seek working media that could (1) operate stably at temperatures up to 250°C; (2) be contained in low-cost metallic materials, preferably mild steel; and (3) generate temperature lifts at least equal to those available with lithium bromide (LiBr) solutions. Physical and thermochemical property measurements were required so that the performance of the fluid pairs in CHP cycles could be calculated.

Desert Research Institute selected an organic pair, trifluoro-ethanol and E-181. This material is stable to 250°C in the absence of air and will generate temperature lifts larger than those available from LiBr solutions (Fig. 4.25). The two liquids are also fully miscible at all temperatures of interest and thus will not form crystalline precipitates at low temperatures or high concentrations.

The fluid mixture selected by Energy Concepts Company is an aqueous solution of three metallic nitrates. The nitrates are $LiNO_3$, KNO_3, and $NaNO_3$ in the proportions 53%, 28%, and 19% by weight, respectively. This solution is thermally stable at temperatures well above 250°C, exhibits negligible short-term attack on mild steel containment, and can reach a higher temperature lift than that of the organic mixture (Fig. 4.25). Because of the solubility limits of the salt mixture in water, some dilution is necessary before allowing it to cool down from operating temperature to

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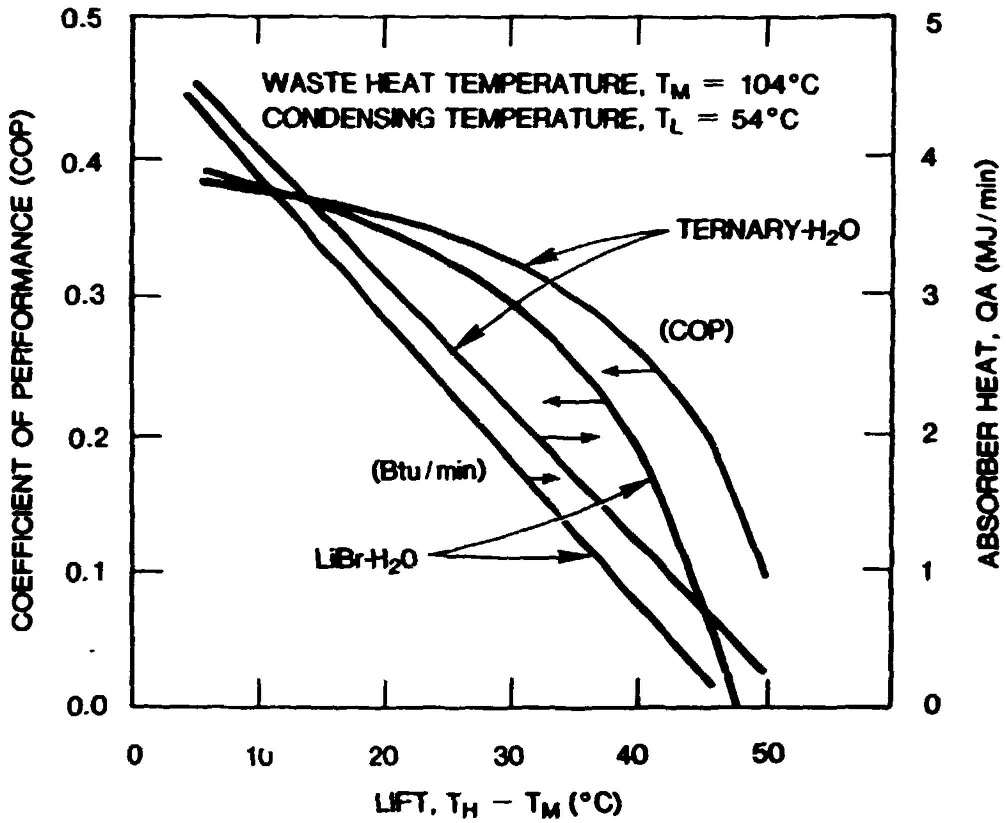

Fig. 4.25. Delivery temperature vs lift for three chemical heat pump working fluids.

prevent crystallization. Figure 4.26 shows the results of a calculation simulating the operation of an absorption heat pump both with LiBr-H_2O solution and with the nitrate mixture. The heat pump described by the calculation is an actual, well-characterized laboratory machine extensively used at ORNL for LiBr experiments.[64] For a representative outlet temperature that lies within the operating range for both fluids, and with heat and mass transfer properties of the nitrate mixture assumed to match those of LiBr solution, the COP of the machine when using the nitrate solution is predicted to exceed that with LiBr at most values of system output.

4.2.9 EPRI Ice Storage Test Facility

J. J. Tomlinson*   M. A. Kuliasha

4.2.9.1 Introduction

Cool storage in commercial buildings for off-peak air conditioning is an attractive load management option for electric utilities. However, a number of studies of commercial cool storage

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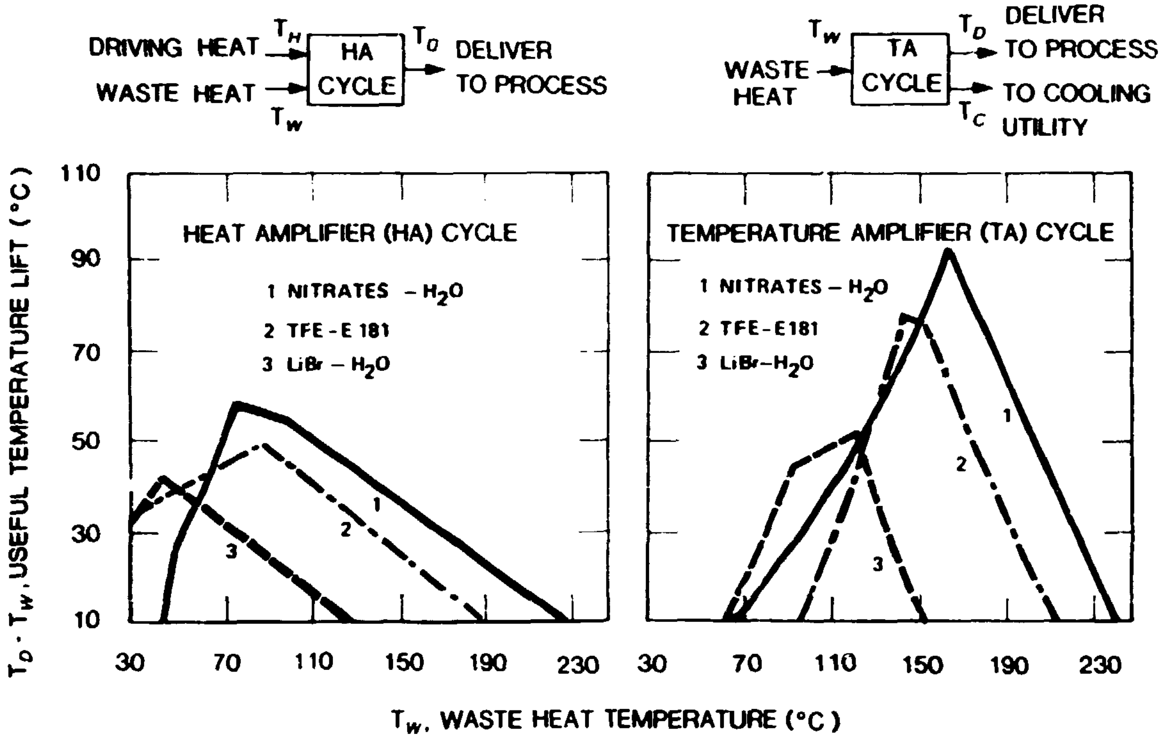

Fig. 4.26. Comparison of calculated heat pump performance of aqueous mixed nitrate and lithium bromide solution.

have found that in many cases, installed ice storage systems did not live up to their potential as effective tools for demand reduction.[65–66] Problems cited included ice storage system component undersizing, poor designs that either led to premature system failure or could not meet the building design cooling load, lack of ice storage performance data upon which solid system designs could be based, and problems arising from the use of HVAC equipment under ice-making conditions.

With support from EPRI, ORNL contacted architects, designers, and engineers experienced in the installation and operation of commercial cool storage equipment to determine the unresolved performance issues for commercial ice storage systems. Issues raised included inadequate information on energy efficiency, the need for optimization of the operation of flooded refrigeration systems, low-refrigerant-suction conditions leading to poor ice-making efficiency, lack of positive oil control designs, nonuniform ice formation and melting, and parasitic energy requirements. Furthermore, it was apparent that many of these issues could be resolved through a thorough laboratory program focused on testing ice storage systems and components according to a standard procedure. As a final step under this preliminary assessment, a set of procedures flexible enough to test ice storage systems over a wide range of conditions and configurations was written.

With a clear need for laboratory testing and a set of test procedures in hand, EPRI contracted Martin Marietta Energy Systems to (1) establish an Ice Storage Test Facility (ISTF); (2) test commercially available ice storage systems under a uniform set of procedures; (3) report the test results in a form useful to designers, engineers and manufacturers; and (4) identify, from experimental results, opportunities for improving equipment design and controls.

4.2.9.2 ISTF design

Design of the ISTF was initiated at the beginning of FY 1986. It was clear from the outset that the facility must contain sufficient flexibility to allow testing of all types of commercially available ice storage systems. These systems are characterized primarily by the type of refrigeration system used.

The most common configuration is one in which an evaporator coil is located in a tank of water and the water is frozen around the evaporator tubing by expanding the refrigerant directly [direct expansion (DX)] into the evaporator coil. A variation of the DX ice system uses a secondary loop containing brine to freeze the water. The compressor, condenser, expansion valve, and heat exchanger constitute a simple chiller system that is used to cool a brine solution (usually ethylene glycol) that is pumped through the ice-making coils. A third type of ice storage system is the liquid overfeed system in which subcooled refrigerant from the high-pressure receiver is metered through a valve into a low-pressure accumulator. Cool liquid refrigerant is then recirculated by a small refrigerant pump through the evaporator coil, where it partially vaporizes and returns to the accumulator. The advantage is increased heat transfer by keeping the inside of the coil continuously wetted with refrigerant rather than only partially wetted as in the DX system.

The dynamic ice maker shown in Fig. 4.27 is an example of a fourth type of cool storage system. This type of unit is fully packaged with a dedicated refrigerant system which freezes (by DX) water that is recirculated over vertical plates above the storage tank. Periodically, sheets of ice that form on both sides of each plate are harvested through a defrost cycle and fall into the storage tank. In addition to flow, pressure, temperature, and electrical power measurements, the amount of ice formed can be determined by measuring the amount of water displaced from the water recirculation system as the freezing process progresses. Diverting the water falling from the plates through a liquid separator connected to a liquid level tank facilitates determination of the amount of ice formed during one or more defrost cycles.

4.2.9.3 ISTF progress

A schematic of the ISTF designed to test each of the four types of ice storage systems is shown in Fig. 4.28. For capacity flexibility, two open-drive compressors, 140 and 211 kW (60 and 40 ton), each with several stages of unloading available, operate in a common refrigerant circuit. Water-cooled condensers matched in size to the compressors can be independently controlled by diverting valves and a control loop responsive to condensing temperature. This combination results in a controlled refrigeration system capable of providing 28–162 kW (8–46 tons) under R-22 saturated condensing temperature and evaporating temperature of 37.3 and −17.1°C (100 and 0°F), respectively. This capacity allows testing of ice storage systems up to approximately 879 kWh (250 ton-h) under the conditions specified in the test procedures. An oil management system consisting of a velocity separator and still was designed to return oil to the compressors at the same rate it leaves in the discharge gas. A surge-type high-pressure receiver and a low-pressure receiver with connections to facilitate liquid overfeed operation were designed, in addition to a small tank to control the liquid level in the low-pressure receiver. A nominal 351-kW (100-ton) dual circuit chiller and a smaller low-pressure accumulator are present in the loop for testing secondary ice storage systems. By valving needed components of the built-up refrigeration system into the loop, the charging (ice-making) performance of vendor-provided ice storage systems of any configuration

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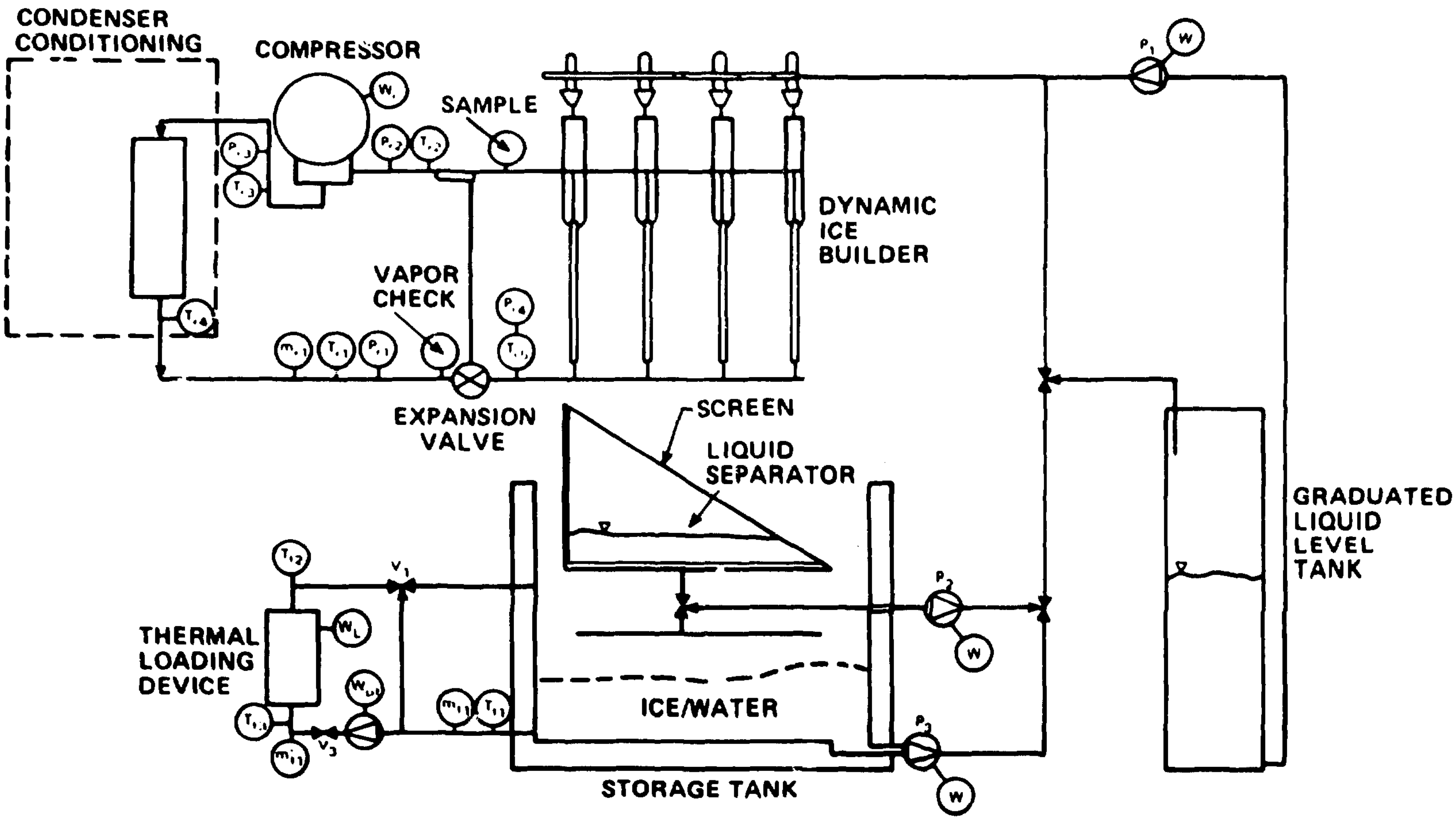

Fig. 4.27. Dynamic ice maker.

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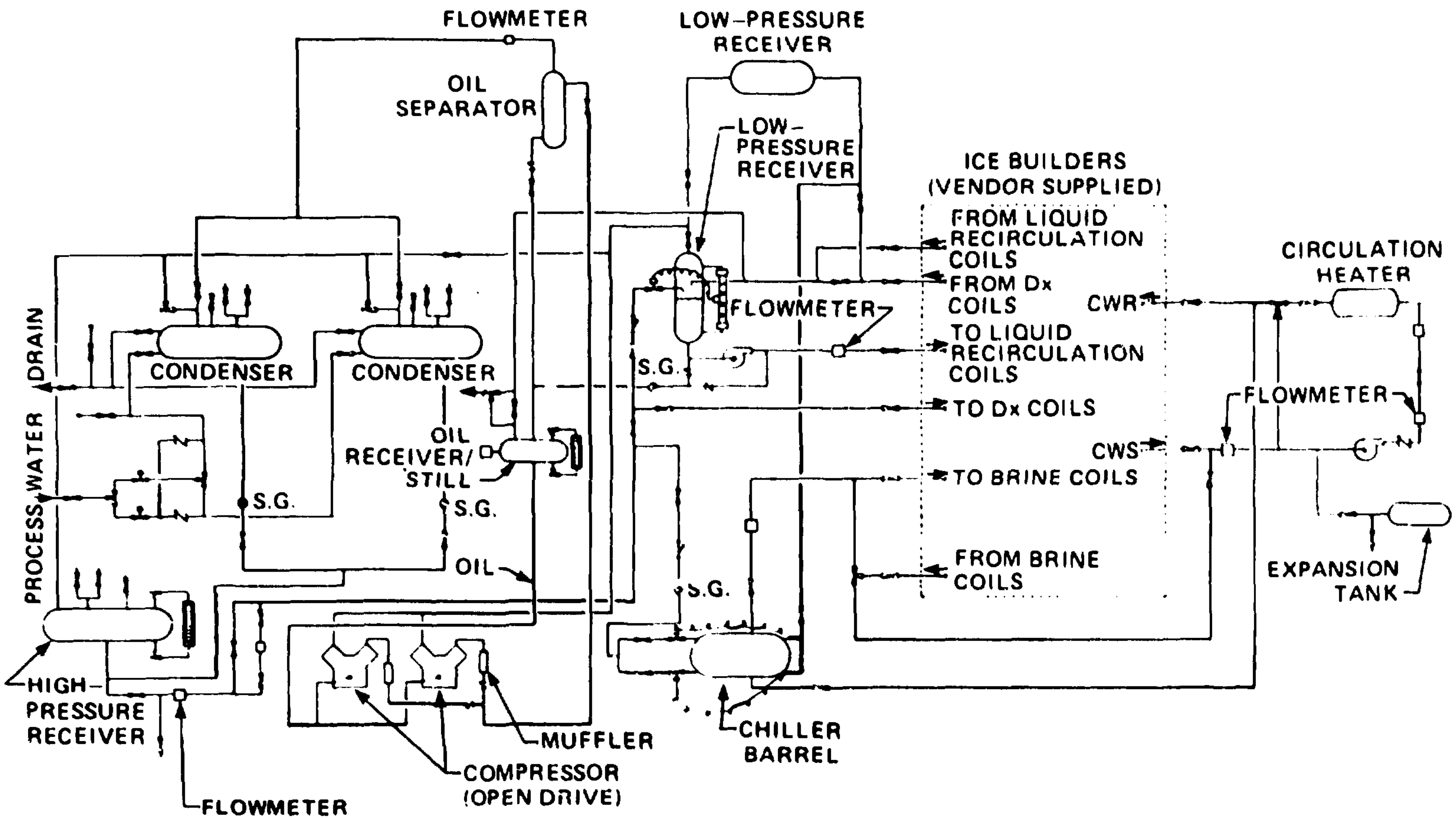

Fig. 4.28. ISTF loop schematic.

can be tested. A 150-kW circulation heater on a power controller and two circulation pumps that can be operated in series or independently allow study of the discharging (ice-melting) process under power conditions of 0–150 kW and 0–45.4 m^3/h (0–200 gpm).

Instrumentation and control systems were designed so that the loop conditions could be maintained according to test procedures. Finally, a small control room to be located adjacent to the test floor was designed.

During FY 1986, all elements of the ISTF design were completed and all major items and loop components were procured. In addition, the test floor and a small control room were installed, and all components (electrical, mechanical, and instrumentation) needed to test a dynamic ice maker were installed. Late in FY 1986, a Turbo model HP300 (40-hp) dynamic ice maker was installed on the test floor. Condenser piping and a water recirculation system were installed, controls from the ice maker were interfaced with the loop control system, and electrical power was run to the unit. Testing of this unit has begun.

The project will continue for the next two years with testing of three more ice storage units. In addition to reports detailing test results, two workshops will be sponsored for dissemination of the technical results of the testing program to building owners, cool storage system designers and engineers, and utility personnel.

4.3 RESEARCH UTILIZATION

As managers for a number of large government programs, and because many of the research areas within the Section are closely related to commonly used products and services, technology transfer is a major activity. A wide variety of mechanisms is used in our technology transfer efforts. Wide dissemination of both subcontracted and in-house research is achieved by the publication of reports and papers, through presentations at technical meetings and workshops, and by the use of industrial and academic advisory committees and consultants. The ERR Section conducted subcontracted research with over 100 organizations, including a number of advanced technology development efforts with manufacturers. Many of the program areas within the Section have industrial advisory groups, including an independent program advisory committee formed by the Air-Conditioning and Refrigeration Institute to review activities related to electric heat pumps, an electric utility advisory group for the work on distribution system automation and control, an advisory committee on electromagnetic pulse research, and industry advisory groups on roofs and foundations. Programs within the Section regularly engage in joint planning and coordination with other research sponsors, including EPRI and GRI. Three staff members were on off-site assignments during the year: one researcher at an industrial subcontractor, one on loan to EPRI to manage and coordinate activities in electric heat pumps, and one who was selected as an IEEE Congressional Research Fellow.

The PSTP personnel assisted the Tennessee Center for Research and Development in preparing a successful proposal for a contract with EPRI to establish a Power Electronics Application Center (PEAC). EPRI's objective is to establish the PEAC to provide a focus for U.S. manufacturers and users in developing power electronic technologies and expanding their application. EPRI is providing approximately $1.5 million over a two-year period. The state of Tennessee will provide $1.5 million in funds over a five-year period to the project. TVA will contribute two staff members for two years, cash contributions for R&D, equipment and facility access, and directed R&D projects. Martin Marietta Energy Systems and DOE will provide access to staff and facilities at the

DOE complex in Oak Ridge. The University of Tennessee, also a participant in the PEAC organization, has established a chair in the Engineering Department for studies in power electronics. TVA will also provide up to $50,000/year to support graduate students. The PSTP will assist the PEAC in the following areas: (1) defining research needs in the field of power electronics; (2) writing an R&D plan; (3) planning research projects; and (4) providing ORNL research facilities as requested. Other specialists from the Solid State, Health and Safety Research, Instrumentation and Controls, Metals and Ceramics, and Physics divisions will also assist as requested. ORNL facilities will be used for research purposes on a selective basis.

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5. Data and Analysis Section

G. A. Dailey

M. R. Leek	V. H. Harley	K. M. Raby	T. D. Wallace
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5.1 INTRODUCTION AND SECTION OVERVIEW

The Data and Analysis Section (DAS) continued to evolve during FY 1985. Some tasks were reassigned to other sections within the Energy Division. For example, responsibility for oversight work for the Energy Information Administration (EIA) was transferred to the Energy and Economic Analysis Section (see Chap. 3). Additionally, the DAS formed a new group entitled the Information Management Group. This group, which is under the leadership of Lynn Duncan, specialized in computer-aided instruction for two Navy sponsors. More information pertaining to Duncan's group can be found in Sect. 5.1.2.

During the year, several important research areas were initiated for our sponsors. Paramount among these was work in data communications through local area networking. This work is funded by the Navy and concentrated on the use of Ethernet networks for local communication and "bridges" for communications between Ethernets. Discussion of this work can be found in Sect. 5.3.1 and is a product of the Data Methods Group. The many sponsors of DAS work during this fiscal year included the Department of Energy (DOE), the departments of the Treasury, Interior, Education, Labor, and Justice, and more than 30 agencies of the Department of Defense (DOD).

The six technical highlights discussed in Sect. 5.2 were selected to emphasize the Section's research accomplishments during the year. When reorganized in FY 1985, DAS lost significant research and development (R&D) capabilities, and much of FY 1985 and a portion of FY 1986 were spent rebuilding. The technical highlights demonstrate the fact that DAS staff were successful in identifying new R&D efforts. The six projects are representative of our R&D areas. These DAS-led projects also involved contributions from other sections of Energy Division, seven other divisions within ORNL and Energy Systems, and a variety of private subcontractors and consultants. Thus, a major responsibility of each DAS research staff member is to participate technically in projects within the Section and provide management direction for the assistance provided by the resources of Energy Systems staff throughout the Oak Ridge facilities and the contributions of the private sector. The ability of the DAS staff to perform in an acceptable technical manner and coordinate projects among a variety of participants has led to our success during FY 1986.

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*Section Finance Officer, Finance and Materials Division.

Much of the work of the DAS falls programmatically within the Data Systems Research and Development (DSRD) Program. This Program is directed by A. S. Loebl, who has responsibilities pertaining to all DSRD activities within Energy Systems.

DSRD has grown extensively because many management information systems (MISs) of the government are based on file maintenance systems designed over a decade ago and, in some cases, the MISs are nonexistent. Most of the systems that the DAS staff reviewed under the DSRD Program are operating on updated hardware, but the application software is based on obsolete technology that is unable to keep pace with current requirements. The outdated software contributes to the reduced efficiency of the updated hardware. In response, the major emphasis of the DAS continues to be design, prototyping, and development of advanced state-of-the-art data systems; however, during FY 1986, DAS work was expanded to include human factors analyses relative to the man-machine interface and data communications. Specifically, the work involved the following:

- Determining the cause of pilot sickness during training on state-of-the-art flight simulators. Paradoxically, this problem becomes more acute as the experience level of the pilot with the actual aircraft increases (see Sect. 5.2.1).
- Examining the communications between local area networks (LANs) to enhance the exchange of information between logical working units with common data requirements (see Sect. 5.2.2).
- Designing integrated data systems that will compile independent data bases (see Sect. 6.1.4).
- Continuing development of computer-aided instruction for the Navy (see Sect. 5.2.3).
- Experimenting with the design of computer operating systems that can be applied to more than one vendor's hardware suite (see Sect. 5.2.4).
- Continuing our design of customized data base management systems (DBMSs) and data base specifications for both classified and unclassified systems within DOE and other sponsor agencies (see Sect. 5.2.5).

In addition, DAS has continued its cooperative research endeavors with the Decision Systems Research Section by funding projects in artificial intelligence (AI), both in applications such as the Detailers' Assistant and in open systems research (see Chap. 6 for further discussion of these projects).

The remainder of this chapter reviews the work of the four DAS groups as they have continued to evolve and discusses the progress made on several of DAS's more significant projects.

5.1.1 Data Methods Group

R. E. Ziegler*

G. O. Allgood†	D. M. Moore§	M. P. Stulberg
M. E. Boling	W. J. Penneweil	S. A. White
L. A. Clinard‡	S. D. Rose	W. B. Wood
D. S. Feezel	J. D. Shelton	
D. S. Hartley, III	C. E. Snyder	

The Data Methods Group (DMG) expanded both its staff and its number of research projects during the year. G. O. Allgood, D. S. Feezel, D. S. Hartley, D. M. Moore, K. M. Raby, S. A. White, and J. D. Shelton joined DMG since September 1985. Among new research areas developed during the year are simulator sickness and physical normalization, the former of which is discussed in Sects. 5.2.1. In addition, the DMG continued research in LANs, contingency analysis simulation, office automation products/impacts, and MIS design methodology.

Several LAN research projects have been conducted by the DMG. One of these involved bridging widely separated Ethernet LANs using the ORNL broadband trunk network (Sect. 5.2.2). The DMG has installed 1500 m of Ethernet cabling in ORNL's main research building (4500 North) to provide a test bed for LAN research and a network for the staff's microcomputers. Further information regarding the LAN and associated research is contained in Sect. 5.3.1.

The DMG's work in military contingency analysis and simulation involves research on the two models in the Modern Aids to Planning Program. These models, State-of-the-Art Contingency Analysis (SOTACA) and Joint Theater Level Simulation (JTLS), are sponsored by the Office of the Joint Chiefs of Staff to support the planning processes of the Commanders in Chief of the various worldwide areas. SOTACA is operational on Energy Systems computers, and JTLS will be operational soon. The provisional evaluation of SOTACA has been completed. Because of inconsistencies between the model as implemented in the code and the data displayed on the screen, recommendations about limiting the use of the present code and future areas of research have been made. An initial enhanced rapid planning model (to avoid some of the problems with SOTACA) has been developed to provide "first cut" contingency planning at a higher turnaround rate than is achievable with the current version. Additionally, an alternate method of modeling attrition, vulnerability, and manpower has been proposed by Energy Systems staff. This alternate methodology increases the theoretical rigor and strengthens the dependence on field data.

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*Group Leader.

†On loan from the Instrumentation and Controls Division

‡Consultant, University of Tennessee.

§On loan from the Biology Division.

5.1.2 Information Management Group

L. D. Duncan*

R. A. Bryant | B. H. Handler | A. F. Huntley
M. A. Buhrmaster† | R. Hume† | S. G. Sparks‡

The Information Management Group was formed in February 1986 and is composed of staff members who have been instrumental in developing new computer-aided instruction (CAI) methodologies for the Navy Management System Support Office (NAVMASSO). Further R&D of improved CAI design and development techniques, which began in FY 1985, has been a major emphasis for the group during FY 1986 (see Sect. 5.2.3). Additionally, group members have performed research in software evaluation and DBMS selection (see Sect. 5.2.4) and initiated a user requirements survey to determine the best approach to CAI for the Naval Aviation Logistics Center (NALC). These projects have enabled the group to investigate key factors in the human-machine interface and to develop techniques that can be applied to a wide variety of computer hardware/software configurations.

The individuals in the group represent applied computer science expertise in several areas. All have direct experience with design and/or development of computer software with an emphasis on the users' interactions with the system. The specific areas of training and experience emphasized within the group include CAI; DBMS; MIS; and high-level, third- and fourth-generation programming languages and tools. To reduce the complexity of problem definition and systems analysis, a rigorous, formal methodology of structured analysis and design is regularly employed in projects performed by the staff. As a corollary, automated design and development tools and techniques are used as often as possible, sometimes in creative and unusual ways.

The group's principal R&D focuses are to (1) provide users of complex data systems with the techniques, tools, training, and understanding to effectively use the hardware and software provided to them and (2) advise organizations how to design and implement computer systems that are effective and efficient from the users' point of view. The emphasis on applications software is significantly different from, and yet complementary to, that in other DAS groups with applied computer scientists specializing in computer hardware, operating systems, and telecommunications. The personnel in the group work in a matrix organization with specialists from other groups as required by specific projects.

The group is currently expanding to meet the staffing needs of funded projects for NAVMASSO and NALC that will exploit the group's expertise in CAI, human-computer interfaces, data base design and evaluation, and MIS.

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*Group Leader.
†Integrated Systems, Inc.
‡Midwest Technical, Inc.

5.1.3 Data Management and Communications Group

S. L. Yount*

F. C. Coleman   M. R. Ives   E. E. Soler†
B. B. Corey   D. Y. Kelly   C. S. Tubbs
N. B. Gove

A major effort of the Data Management and Communications Group continued to be the support of the Navy Civilian Personnel Data System (NCPDS) Project. As of September 30, 1986, 82 Navy and Marine Corps civilian personnel offices and 19 Department of Labor sites were implemented on this system. The personnel records of employees serviced by these offices comprise 52% of the projected total of 399,000 when all offices are on-line. With the current NCPDS Computer Facility equipment rapidly approaching operational capacity, coupled with a requirement to meet the user site implementation schedule and to maintain acceptable user response time, aggressive capacity planning and traffic management efforts were required to ensure optimum utilization. Plans have been completed for a building expansion, test and acceptance of a major equipment upgrade, and reconfiguration of the facility equipment during FY 1987 to provide capacity for further site implementation.

Following a major revision of the NCPDS Safety and Security Plan, a formal security survey and a risk assessment of the facility were conducted using the basic methodology approved by the Department of the Navy. Other efforts in support of NCPDS include (1) analysis o Continuity of Operations Plan alternatives, (2) participation in working groups formed to develop interfacing between NCPDS and other Navy systems and development of a headquarters-level civilian employee personnel system to parallel NCPDS, (3) development of plans for migration of NCPDS to the Defense Data Network, and (4) planning for replacement of Burroughs equipment with that of Sperry during Phase IV of this project.

The Data Management and Communications Group will be relieved of responsibility for operation of the NCPDS Computer Facility early in 1987 when the Department of the Navy establishes a direct contractual relationship with a commercial contractor for these operations. Thereafter, the group will provide only technical support to this project. This planned reduction of effort has allowed the group to initiate work in support of numerous other projects.

The following projects were either completed or initiated during the year for the Assistant Comptroller of the Navy for Financial Management Systems:

- In support of the Standard Automated Financial System (STAFS) Project (a financial support system to be installed at all Navy Industrial Funded Activities), a third party review and evaluation verified the design of this system; and a formal conversion cost analysis was completed.
- Work began on the evaluation of alternatives to effect interfaces among the Navy Standard Civilian Pay System, NCPDS, and STAFS.

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*Group Leader.
†On loan from Computing and Telecommunications Division.

For the Commander, Navy Reserve Forces, a study project was completed to determine the requirements for an organizational restructuring and adoption of procedures to accommodate the integration of Department of the Navy–established data management functions and concepts into this headquarters organization.

For the Assistant Comptroller of the Army (Finance and Accounting), the following projects were initiated:

- Design of an automated data processing (ADP) system for inventory control of all ADP hardware and software assets used in support of financial systems throughout the Department of the Army.
- Design of the Data Administration Management System. This system will provide for a standard view of all of the Army's financial ADP systems, showing major components, interrelationships and intrarelationships of data, programs, systems, and organizations.

Work was also initiated on the design of the Safety and Hazard Abatement Information Management System for the Naval Safety Center. This system will be used to store data and provide information relating to accidents and occupational hazards throughout the Department of the Navy, including all Naval aviation activities, surface ships, submarines, diving units, and shore activities.

Technical support to the DOE Office of Scientific and Technical Information (OSTI) continued to be primarily in the analysis of OSTI's existing systems, development of systems enhancements, and refinement of the capabilities of their BASIS DBMS (see Sect. 5.2.5).

Technical support to the Information Research and Analysis Group of the Biology Division continued in the area of project information systems, particularly those involving the INQUIRE Data Base Management System. One group member was on loan part-time for the majority of FY 1986 to head a team formed to develop an Energy Division Project Information System. The group provided support and consultation for a variety of other DOE and Work-for-Others projects, including the Army ADA-AWIS Design, the chemical separations science information retrieval system, AI systems for reactor control, LAN studies, and various communications studies.

Scheduled project work fully corresponds to the assigned function of the group—R&D in the general areas of large DBMSs and data communications.

5.1.4 Data Systems Applications Research Group

S. Cantor*

R. W. Barnes	A. J. Klein	K. E. Shaffer
H. W. Bertini†	A. R. Sadlowe‡	F. J. Smith§

The chief application area for the Data Systems Applications Research Group lies in defense logistics (predominantly for the Navy). In this context, logistics means the art and science of engineering, technical, and managerial activities concerned with the requirements and designs, as

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†Engineering Technology Division.
‡On loan from Engineering Division.
§On loan from Chemistry Division.

well as supplying and maintaining resources, to support military objectives, plans, and operations. Therefore, our primary R&D goals are to advance, adapt, and develop information science technologies and concepts for various logistic functional areas, such as maintenance, inventories, transport of personnel and equipment, personnel training, and other areas.

In FY 1986, work progressed for a number of DOD organizations in the following logistic-related projects:

- Assistance to the Naval Aviation Logistics Center (NALC)
  - — In reviewing and evaluating machine-readable identification methods with an emphasis on selecting identifiers that can survive certain harsh environmental conditions (elevated temperatures and/or salt-laden atmospheres).
  - — In developing a computer program, written in PROLOG, for evaluating failure rates of aircraft components via multivariate regression analysis. The program will eventually have "smart" capabilities (e.g., detection and correction of erroneous data).[1]
  - — In improving CAI for using the Naval Aviation Logistics Data Analysis System.
  - — In evaluating aircraft maintenance-engineering analytic techniques (in support of NALC's response to the Coopers and Lybrand study of the Naval Air Rework Facilities).

- Assistance to sponsors concerned with military transport: Military Sealift Command and Military Traffic Management Command
  - — In surveying commercially available microcomputer-based vehicle routing and scheduling program packages with respect to their cost, capabilities, and characteristics. Four relatively inexpensive packages (costing <$2,000) were tested on an IBM-PC/AT via demonstration diskettes; two of the packages were capable of solving most vehicle routing problem constraints for two versions of 21-city and 30-city problems.

- Assistance to the Navy Supply Systems Command
  - — In evaluating a single-source methodology for translating machine-dependent COBOL to a machine-independent source code that had been developed for conversion of a large data system. A representative application of 18 functional applications of the Uniform Automated Data Processing for Stock Points served as a prototype demonstration of the methodology and subsequent retention of application functional capabilities; approximately 65,000 lines of COBOL-68 source code were successfully converted to COBOL-74 source code.[2]
  - — In planning and initiating a beta test of the Texas Instruments' Information Engineering Facility (IEF) software package. IEF, an integration of the information engineering methodology with automated system design tools, is being evaluated and tested for design applications of large-scale data systems; approximately 25% of the Uniform Automated Data Processing System for Stock Points will be redesigned using the IEF.

- Assistance to the Naval Sea Systems Command
  - — In designing, developing, prototyping, and evaluating systems [including expert systems in cooperation with the Decision Systems Research Section (see Sect. 6.2.4)] to improve managerial control of budgets and operations for Naval repair and maintenance facilities.
  - — In designing, developing, and prototyping data systems and engineering methodology to assemble technical data required for competitive procurement of selected spare parts (and similar assistance to the Army Aviation Systems Command).

— In assessing selected advanced technologies being developed for Naval industrial facilities.

- Assistance to the Naval Regional Data Automation Center (NARDAC)

  — In designing, prototyping, and evaluating data systems related to the administrative management of a broad spectrum of Naval logistics and support activities.

  — In formulating plans for using AI methodologies for selected NARDAC technical functions.[3]

- Assistance to the Marine Corps

  — In designing a prototype reliability-centered maintenance information analysis center.

  — In continuing a comprehensive evaluation of engineering changes proposed for amphibious vehicles.

The group is expanding to meet the staffing needs of funded project areas. However, the complexity and volume of the group's work are such that much of it must be performed with the assistance of other Energy Division sections, other ORNL divisions (Engineering Technology Division and Instrumentation and Controls Division), and Energy Systems support organizations (Engineering Division and Computing and Telecommunications Division); a number of subcontractors are also assisting in this work.

5.1.5 Systems Analysis Group

C. E. Hammons*

K. R. Carr J. L. Christian P. B. Zuschneid

The Systems Analysis Group is composed of individuals with applied computer science and electrical engineering backgrounds who have expertise in operating systems, information management, telecommunications, systems analysis, hardware and software systems design, and systems configuration management. The individuals in this group provide R&D primarily in the DOE's Work-for-Others programmatic area.

Currently, the group is providing support for the Shipboard Nontactical ADP Program (SNAP) for the Navy Management Systems Support Office in Norfolk, Virginia; NALC; and the Navy Safety Center. The group is participating in applied R&D in computer science relative to the needs of each sponsor. As part of the DAS's support for these projects, the group has contributed in the following areas: (1) systems performance analysis, (2) CAI with AI/natural language extensions, (3) expert systems support of the fleet SNAP trouble desk, (4) evaluation of DBMS systems for SNAP, and (5) hardware independent operating systems.

*Group Leader.

5.2 TECHNICAL HIGHLIGHTS

5.2.1 Inertial and Control Systems Measurements of Flight Simulators for Evaluation of the Incidence of Simulator Sickness

G. O. Allgood*

R. C. Muller* W. D. Strunk†

R. M. Tuft* B. W. Van Hoy†

The U.S. Navy has in its training equipment inventory Operational Flight Trainers (OFTs) built to emulate the characteristics of particular aircraft. These systems are designed to supplement active training by providing a broad spectrum of capabilities ranging from operational and tactical scenarios to emergency situations. These systems are flexible, cost-effective, safe, and important to DOD for training. The use of these simulators by air crewmen, however, occasions a disease known as simulator sickness. The symptoms of this malady are analogous to those of motion sickness and can produce long-term residual aftereffects that restrict fleet operational readiness and reduce training effectiveness. The genesis of this disease is dominated by visual presentation and the subsequent human interpretation of scene content, with system motion base dynamics acting as a lesser causative factor.

The Navy has conducted studies of simulator sickness for many years in hopes of providing a unified theory that models the interaction of the simulator's visual and motion base systems with the human's vestibular and visual system dynamics. These efforts have included surveys, literature reviews, and field and experimental studies to better define the problem. One outgrowth of this work has been the development of a theory supporting the motion base arguments that pilot and simulator interaction creates low-frequency characteristics that induce simulator sickness. These dynamics are believed to be introduced into the system through pilot-induced oscillations. These suspect energy spectra are identified in MIL-STD 1472C, which establishes criterion levels of exposure to very-low-frequency vibrations. This standard maps onto the acceleration-frequency plane "percent population sick" surfaces, which are a function of statistical population and time.

To test this hypothesis, DAS was tasked to measure and analyze the motion base dynamics of two Navy OFTs to determine the presence or absence of these very-low-frequency vibrations with the pilot in the loop. The simulators, 2F64C SH-3 Sea King ASW Helicopter and 2F87F P-3 Orion ASW fixed wing, were chosen because of the high incidence of simulator sickness in the former and the low or nonexistent incidence in the latter. The systems were instrumented with high-accuracy linear accelerometers to measure low-frequency vibrations in the roll, pitch, and yaw axes along with the pilot's input signals (stick, collective, and cyclic) and computer command signals (output to motion base). Sufficient data accuracy was maintained to obtain important phase and time relations for correlation studies.

Modal analyses were conducted in situ to quantify any local modes that would affect data measurements. Both trainers were found to be linear without resonances below 100 Hz in the areas where the transducers were mounted. The locations of the transducers were chosen to correlate with

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*On loan from Instrumentation and Controls Division.
†On loan from Engineering Division.

pilot and copilot exposure, with x-axis representing tail-to-nose, y-axis representing lateral wing-to-wing, and z-axis representing vertical through-the-spine measurements.

The results from the analyses show that a high incidence of sickness is found in the helicopter simulator, with energies routinely exceeding the standards established in MIL-STD 1472C. For the fixed-wing system, this is not the case. These findings are graphically depicted in Fig. 5.1, where a plot of the nominal values for the three axes of the SH-3 and the P-3 x-axis is presented along with "2% population sick" regions, which are identified by the shaded surfaces. The data curves represent ensemble averages for 2-h syllabus hops. The nominal values for the measured A_y and A_z for the P-3 are not presented because their magnitudes are so small compared with plot resolution that the two data curves end up being superimposed on the frequency-axis.

The graph also identifies characteristics of the systems that were invariant throughout the analyses. The measured accelerations in the three axes for the helicopter always had the same relative orientation (i.e., $A_y > A_z > A_x$); measured accelerations in these axes were, in the

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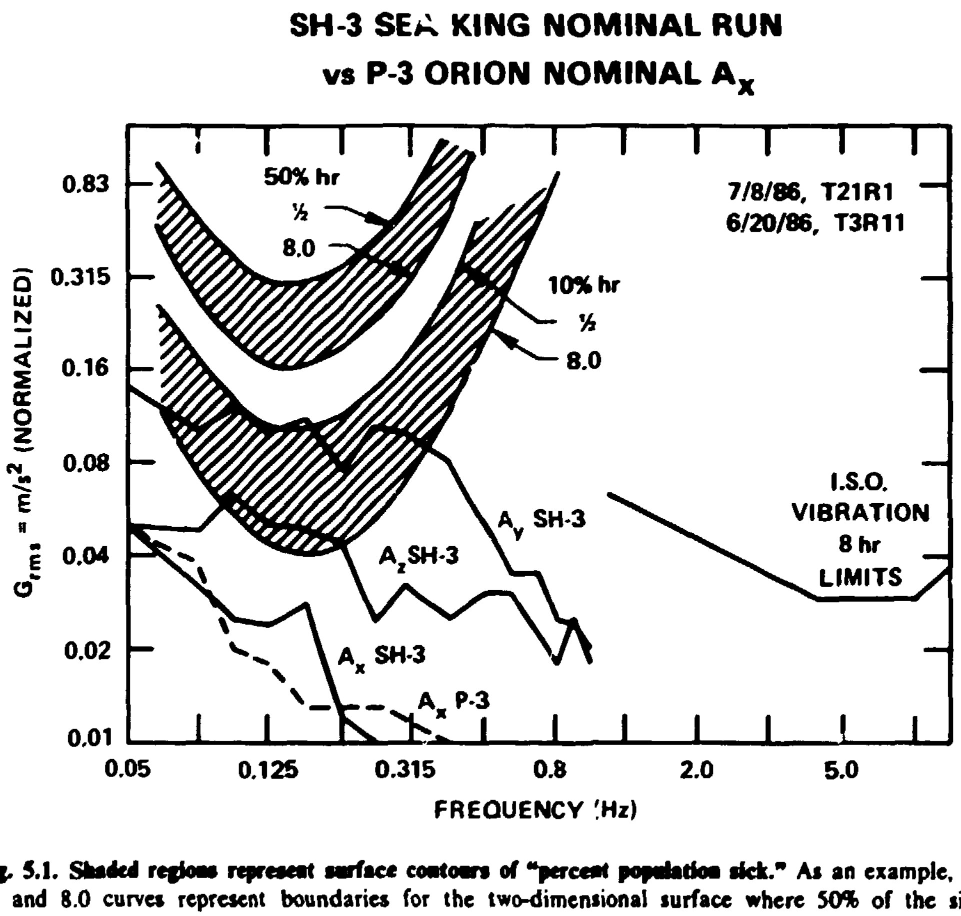

Fig. 5.1. Shaded regions represent surface contours of "percent population sick." As an example, the 50% hr 1/2 and 8.0 curves represent boundaries for the two-dimensional surface where 50% of the simulator population gets sick as a result of exposure-use for 1/2- and 8-hr durations for varying degrees of energy. Also included is the International Standards Organization vibration standard for frequencies beyond 1.0 Hz and 8-hr duration. Plotted curves represent ensemble averages of energy spectra (in SI units of G_{rms} = 9.75 m-sec^{-2}) for x, y, and z axes for SH-3 SEA KING (solid curves) and x-axis (dashed curve) for P-3.

statistical sense, greater than the corresponding axes measurements for the fixed-wing simulator; and the acceleration in the x-axis (A_x) for the P-3 was always greater than that in A_y or A_z.

Closure problems developed in the subsequent analysis when fast Fourier transform (FFT) ensemble averages were used in the syntheses of a frequency model. Figure 5.2 is a visual interpretation of this paradigm, where τ_1 and τ_2 represent the body's biological time constants of getting sick and then discharging the sickness, respectively. As shown, a pilot who experiences high activity in the early stages of his hop will not exhibit symptomatology characteristic of simulator sickness, even though his energy level exceeded his threshold for accommodation. This is because of the body's ability to shed the sickness during a period of low activity. Assume that the same pilot, with all system and physiological variables unchanged, experiences the same activity at the end of his hop. Upon exiting the simulator, he complains of sickness because he has had insufficient time to discharge the disease, although the FFT ensemble average is the same as before. This contradiction was solved in the development of three parameters, identified as activity number, a function of time; beta factor, a function of the power spectral density function; and the susceptibility number, a function of the activity number and beta factor.

The conclusion from the study is that the pilot/simulator interaction does introduce frequencies into the system that are recommended against by MIL-STD 1472C and that the principles of this standard should be implemented for service-wide acceptance testing by DOD. This recommendation and that of the development of a biomechanical device to measure the motion base dynamics were accepted by the Navy.

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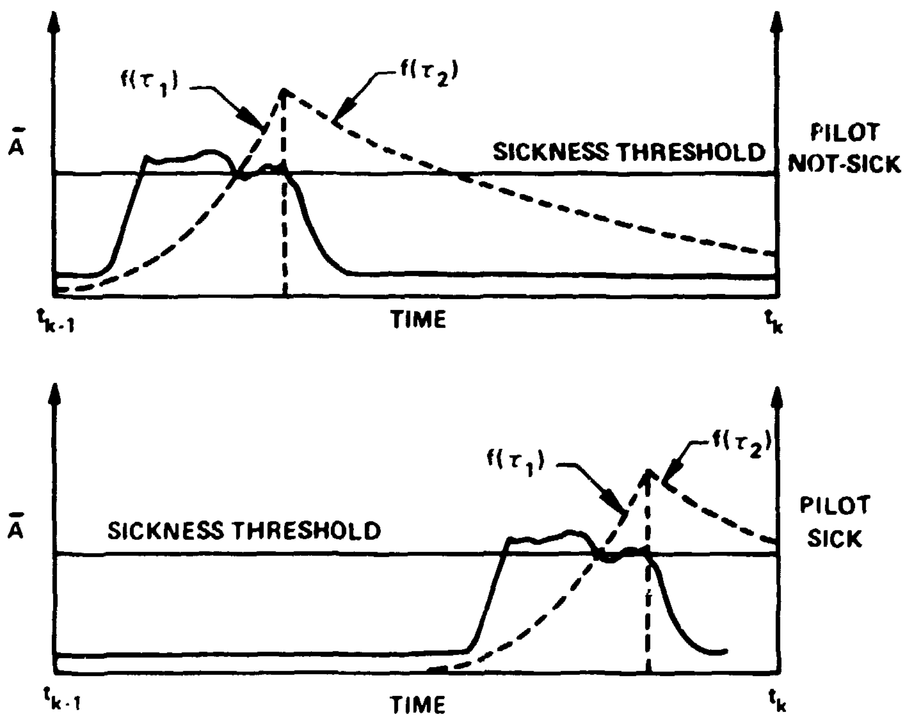

Fig. 5.2. Pilot's physiological response to system activity and contradiction resulting from ensemble averaging of spectral energy.

5.2.2 Experimental Bridging of Widely Separated Local Area Networks

W. B. Wood

The Oak Ridge computing and data communications environment is diverse and complex, with a very large and powerful collection of data processing equipment located over the three-plant complex. The requirements for information sharing between these computing resources and their users are significant. The Ethernet LAN has evolved at each site as the preferred departmental level network for high-speed data communications. Because of distance limitations inherent in the Ethernet technology, these networks are geographically local in nature. The ability to interconnect these numerous LANs into a high-speed data communications internetwork would greatly expand the research computing capabilities of the technical and scientific communities.

The objective of this experiment was to provide a test bed to evaluate the connectivity of widely separated (up to 20 miles) Ethernet LANs using the existing ORNL broadband trunk. Market research resulted in the selection of the Applitek Corporation's NI10/E Ethernet Bridge as the only product that would satisfy the requirements. The Applitek product provided the following new and unique bridge technology:

- Media independent—can use broadband, fiber optic, or microwave trunk media technology.
- 10 Mbps channel speed in a 6-MHz standard channel.
- Access method—provides both token passing and carrier sense multiple access with collision-detection-like performance concurrently.
- Frequency agile radio frequency (RF) modem—operates on any 6-MHz channel from 20 to 375 MHz and is software selectable.
- No distance limitations—Ethernet LANs may be separated by more than 20 miles.
- Protocol insensitive—supports any mix of high-level network protocols.

Three bridges were procured and brought on-line during February 1986. Figure 5.3 illustrates the multiple bridge test sites and Ethernet LANs that were interconnected during the experiment. Initially, the bridges were installed to provide connections between the Computing and Telecommunications Division (C&TD), the Energy Division, and the Y-12 Plant's Fusion Energy Division's Ethernet LANs.

Ethernet LAN connectivity bridged via the broadband trunk was demonstrated both within ORNL and between ORNL and the Y-12 Plant (a distance of 7 miles). The connected LANs appeared as one logical Ethernet LAN. The bridges supported the high-level network protocols DECnet, XNS, and TCP/IP transparently. Services including mail, file transfer, and virtual terminal operated correctly over the bridges. Data bit rates in excess of 1 Mbps (using the maximum packet size) were demonstrated. The bridges successfully handled the routine daily traffic between the two plants (C&TD X-10 Ethernet to the Fusion Energy Division Y-12 Plant Ethernet) in place of the existing 9.6 Kbps. The bridges successfully filtered traffic, permitting only remote traffic to pass to the broadband trunk, with local LANs seeing only the trunk traffic that was addressed to them.

Difficulties encountered during the initial testing phase were as follows:

1. Initial bridge operation was delayed because of broadband trunk signal interference from the Oak Ridge Gaseous Diffusion Plant (ORGDP) Sytek bridge. The Sytek bridge was operating at

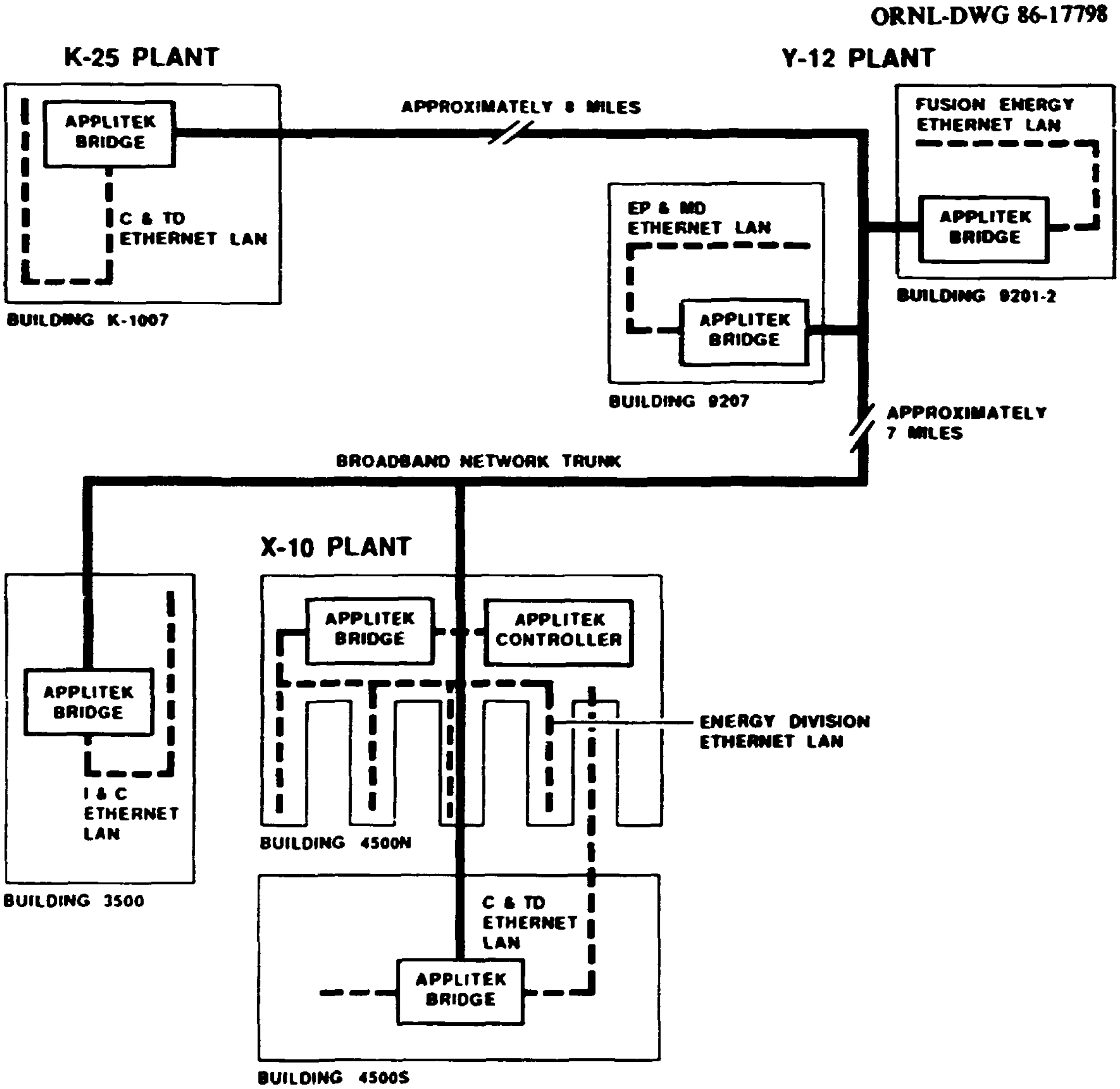

Fig. 5.3. **Bridge Test Sites.** Widely separated Ethernet LANs were used as bridge test sites.

25 dbmv above its nominal level, 6 MHz from the Applitek frequency channel. The Sytek bridge output was reduced to nominal levels, resulting in the Applitek bridges coming on-line in a stable condition.

2. The Applitek bridges experienced several externally induced failures resulting from broadband problems such as a failed broadband amplifier, a broadband loose connection, and several occurrences of thunderstorm-induced outages that caused the broadband network to fail.
3. The Applitek bridge installed at the Y-12 Plant's 9201-2 building test site operated intermittently because of site-specific RF and/or electrical interference. The bridge operated successfully at adjacent Buildings 9201-3 and 9207. Applitek field engineers provided configuration changes in the form of improved chassis grounding and automatic reset firmware that allowed the bridge to operate successfully in the 9201-2 environment.

With these difficulties corrected, the bridges have operated without incident and have demonstrated extremely reliable and acceptable service.

Three additional bridges (for a total of six bridges) were procured (by C&TD) as a result of the successful initial tests and are now connecting Ethernet LANs from all three plant sites. Figure 5.4 illustrates the resultant Oak Ridge Internetwork. The ORGDP bridge connection provides high-speed data communications to ORGDP's computer resources, including the Cray computer.

This experiment has provided a solid basis for proceeding with the three-plant internetwork. The bridged LANs using the existing broadband provide a network of sufficient coverage, capacity, connectivity, and reliability to satisfy the current and near-future needs of the Oak Ridge complex. Using the existing broadband, coupled with the relatively low cost of the bridge ($12,500), makes this network solution extremely cost effective and practical. Future demand for increased network capacity and reliability, where and when it is needed, can be met by integrating the fiber optic technology into the broadband internetwork.

Experimental research is proceeding to provide a pilot network with both the fiber optic and broadband physical media. The pilot network will provide the following data paths:

- Ethernet to Ethernet over broadband media.
- Ethernet to Ethernet over fiber optic media.
- Ethernet to Ethernet across both media with a media bridge.

This fiber optic research will provide a path to new technology while allowing continued use of the broadband resource into the future.

5.2.3 SNAP-I CAI Prototype

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M. A. Buhrmaster*   C. E. Hammons   A. F. Huntley
J. L. Christian   B. H. Handler   S. G. Sparks†

Research and development of CAI for the Shipboard Nontactical ADP Program (SNAP) is a major multiyear project that began in FY 1985. The Shipboard Uniform Automated Data Processing System—Real Time (SUADPS-RT) was selected as the SNAP application system for prototyping CAI. This operational software is used by shipboard storekeeping personnel to perform routine supply functions. The prototype CAI system was completed and delivered to NAVMASSO.

During the first two years of R&D devoted to this project, ORNL has developed a set of new techniques for development of CAI that rivals and surpasses most commercially available authoring systems in many ways.[4] NAVMASSO considers training through the use of CAI to be a highly desirable alternative for both initial and follow-up presentation of material pertaining to their SNAP applications Computer-based training is considered to be a critical factor to the overall success of the SNAP program, especially because of a shortage of training personnel, frequent personnel rotation, and the large number of self-contained operational computer systems. After formal presentations to the Navy in October and November 1985, several revisions were made to

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ORNL-DWG 86-17799

OAK RIDGE NETWORK

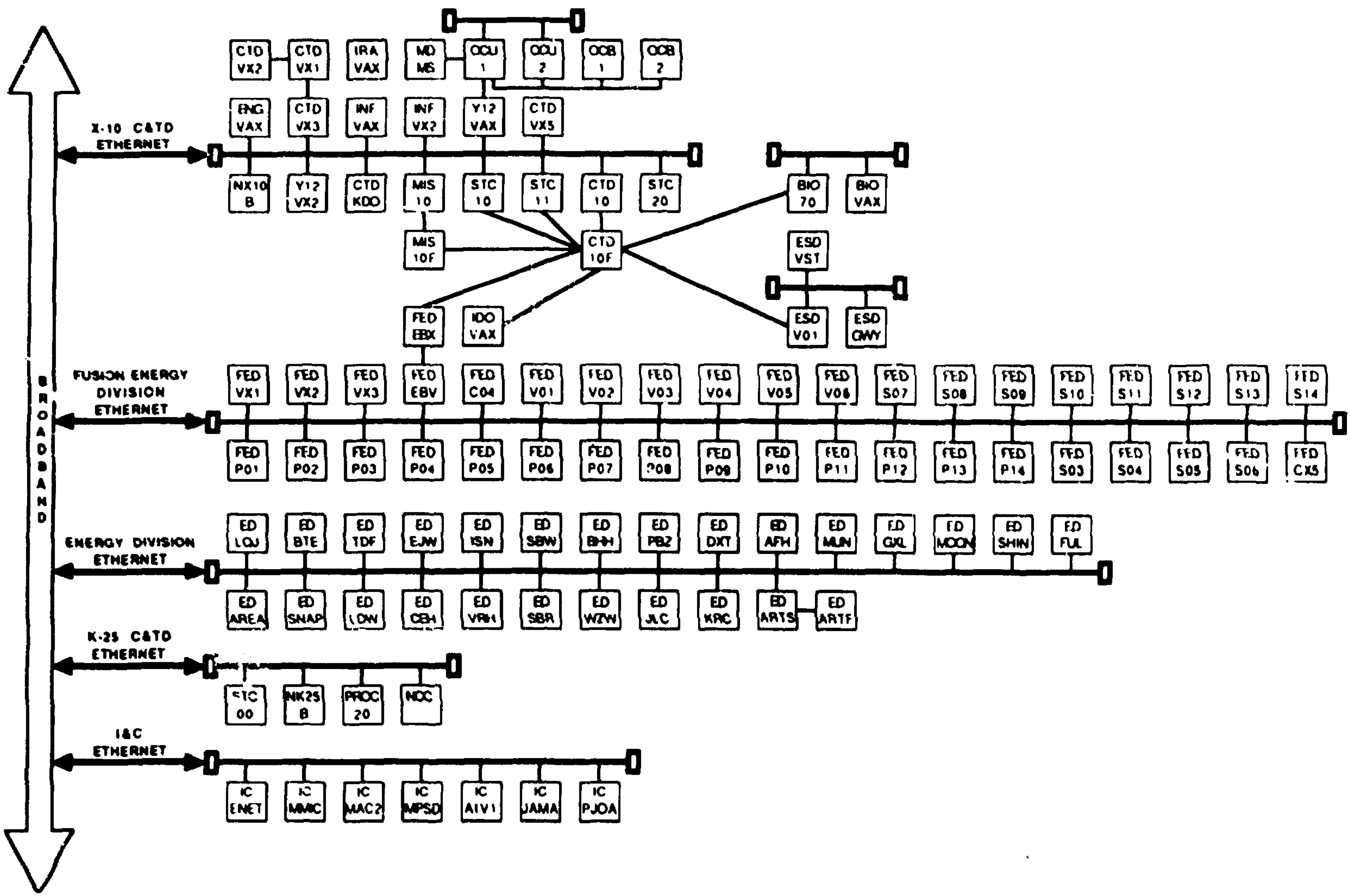

Fig. 5.4. Oak Ridge Internetwork. The bridges interconnect widely separated LANs to form one logical Oak Ridge Internetwork.

the original CAI prototype. One of the most significant enhancements has been the development of a new loading method.[5] Instead of the 3- to 4-h procedure previously required, it can now be completed in six steps requiring less than 30 min. Memory requirements have been significantly reduced, and modifications allowing the use of Data Management 6 Transaction Processing (DM6TP) software for the CAI have been made. The DM6TP-based CAI system is the first to be implemented from the beginning using NAVMASSO's distributed processing standards and facilities.

Another very significant accomplishment in this project was the use of automatically generated COBOL code, which is incorporated in the programs through the use of the COBOL COPY verb. This method of building lesson programs allows modifications and corrections to be made in one place—the COPY block. Recompiling the code inserts the correct changes into each program. If new lessons are desired for SUADPS-RT or any other SNAP-I application, essentially *no new COBOL code* needs to be written. Approximately 20,000 lines of code have been generated through this automatic process, resulting in a tremendous savings in time and the production of major segments of guaranteed error-free code (see Fig. 5.5).

ORNL-DWG 87-11921

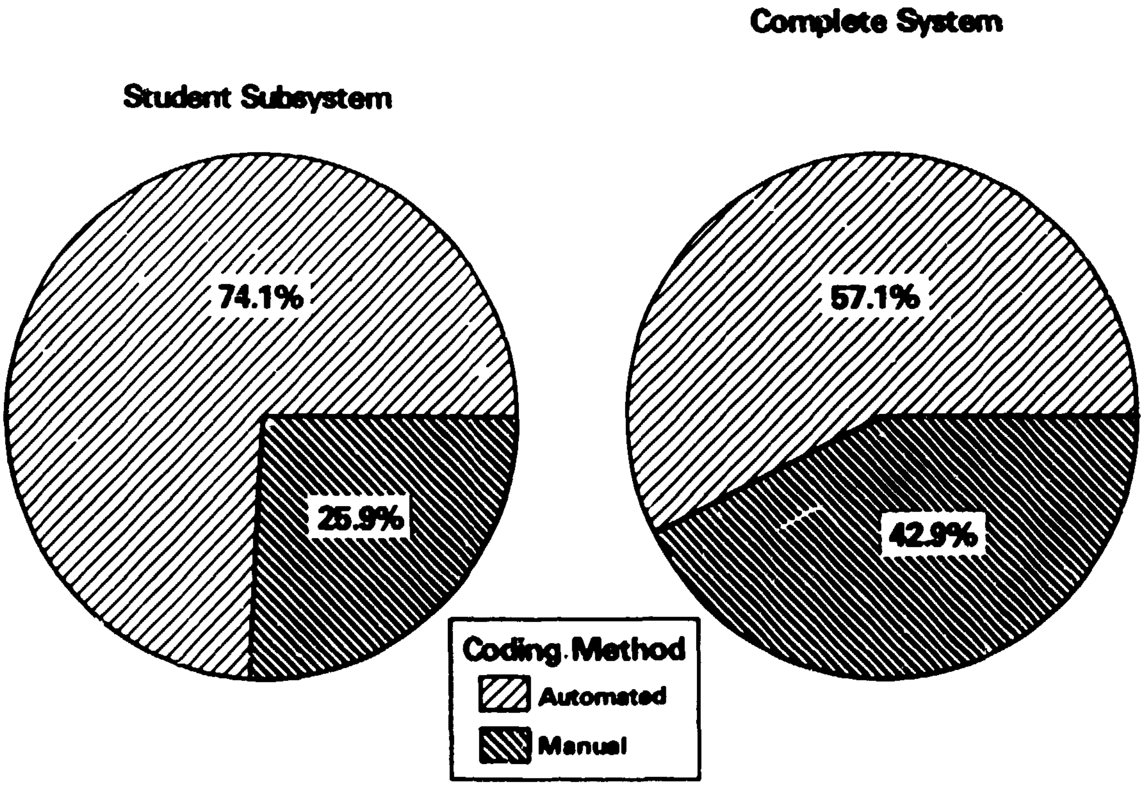

Fig. 5.5. Magnitude of automated code generation. Includes student and administrator subsystems.

5.2.4 Data Base Management System Evaluation Methodology

A. F. Huntley

NAVMASSO provides systems support for the Navy's SNAP computer systems. Equipment used by SNAP consists of the SNAP-I computer system, a Honeywell DPS-6 minicomputer, used on large ships such as aircraft carriers; the SNAP-II computer system, a Harris 300 minicomputer, used on smaller ships and submarines; and Zenith personal computers for use as intelligent terminals. ORNL has developed a SNAP "Center of Excellence" to provide research support to NAVMASSO. SNAP hardware configurations have been installed and are being used for various R&D activities, including the development of a SNAP-I prototype software, hardware interface testing, expert systems research, and possible development of a hardware-independent operating system.

NAVMASSO has also requested assistance in the selection of a standard DBMS to support the SNAP program. Requirements include that the DBMS operate on each of the three SNAP target hardware systems. In preparation for the SNAP DBMS evaluation, ORNL has developed a DBMS evaluation methodology.[6] The report discusses traditional computer software evaluation methodologies, with identification of aspects that may cause the resulting evaluation to be deficient. Traditional software evaluations may rely too heavily on information provided by vendors or interviews with current users of the software and too little on actual hands-on testing by the people who will be using the software for development work. The format of the final report of the software evaluation team is usually oriented toward some form of features checklist for use by management. Such a format may limit the depth of analysis performed by evaluators, causing them to perform only enough testing necessary to fill out the checklist. Benchmark test results may also be overstressed, with minimal attention paid to the actual functionality of the software. A DBMS evaluation methodology is then proposed which stresses the layered functionality of the software. The methodology requires a large amount of hands-on testing and allows team members to evaluate the software from the perspective of application developers and end users who will use the system on a day-to-day basis. Such an approach starts with the testing of the basic capabilities (the high-level functionality) inherent in the type of software being evaluated. Testing of the various modules of the software continues until specific information about the implementation of features can be gathered. Idiosyncrasies of the various means of implementation determine the true limitations of functionality of a software package.

During the preparation of a methodology report, several general items must be evaluated. These items form a supportive environment for the DBMS and enhance the usability of the software, although they may not affect its intrinsic functionality. Included in the evaluation are features such as the installation procedures for the software, documentation, system integration, system portability, and vendor and product stability. A set of technical facilities provided by DBMS software is then presented for analysis. This set includes items such as the data manipulation language, report generators, application development subsystems, host language interfaces, integrated data dictionary, and data base integrity and security facilities. Areas where these facilities may not meet the desired functionality are also identified. The methodology provides a means of determining the functionality of DBMS software. In-depth hands-on testing of all of the software's facilities is the key to determining whether the system's capabilities will meet present and future requirements. The depth of analysis allows identification of idiosyncrasies of implementation, which determine the true functionality of the DBMS. The methodology has proved useful in performance of DBMS evaluations and data base analysis for NAVMASSO and other sponsors.

5.2.5 Information Automated Retrieval System Development for the Department of Energy/Office of Scientific and Technical Information

B. B. Corey

In response to the changing needs of the DOE research community, OSTI made a commitment at the beginning of 1986 to provide an enhanced computer system which not only provided retrieval of research reports but also supported new and advanced needs that had not previously been met through their existing computer systems. In support of this project, the Data Management and Communications Group supplied expertise to analyze the existing information retrieval system and recommend which capabilities would be needed.

The project involved relocating portions of both DOE and non-DOE data bases from the DOE/REmote CONsole (RECON) system to a VAX 8600 and changing from the DOE/RECON software to a commercial data base storage and retrieval system called BASIS, which is designed to provide on-line access to textual data bases. Capabilities of both DOE/RECON and BASIS were analyzed in detail by ORNL and presented to OSTI. Alterations were made to the BASIS command language to ensure that users switching from DOE/RECON to BASIS would have a smooth transition. In some cases, software interfaces were written by ORNL to simulate commands from DOE/RECON. A load analysis was performed by ORNL, and recommendations were submitted for the speed and memory requirements of BASIS on the VAX to ensure that the number of simultaneous RECON users supported by the IBM 3033 could be handled. Disk space calculations were made and reported to OSTI. This information, in addition to the load balancing recommendations, became an important part of the initial hardware procurement.

In addition to using the BASIS data bases for retrieval, OSTI also plans to use output from the system to produce publications and to provide automatic searching for users to keep up-to-date with a specific area of interest. To fulfill this need, the data bases were carefully designed to ensure that information, if altered during loading of the data base (for retrieval purposes), could be returned to its original text for output to the end user. For instance, the publication date, which is usually entered as "month, day, year," must be converted to a YYMMDD (YearYearMonthMonthDayDay) format for searching date ranges. However, in a printed product, the original format is usually preferred. Prototype data bases were designed by ORNL for each new OSTI Automated Retrieval System (OARS) data base, and testing was done by designer and end user before the actual production data base was loaded.

Future work with OSTI will involve designing maintenance software for OARS data bases to perform complex validation not available as part of the commercial BASIS package. The software will provide an interface between the BASIS software and OSTI's authority system. The authority system includes information on all DOE reports, conferences, corporate sponsors, and research institutions.

OARS is a very important part of a larger project known as the Integrated Technical Information System (ITIS). The end user logs into OARS through ITIS and gets a menu of possible alternatives, which will consist of handling electronic mail, reviewing the output from automatic searches, or performing searches on several retrieval systems, including OARS, DIALOG, and the National Aeronautics and Space Administration/RECON (see Fig. 5.6). ITIS will perform automatic dialing of outside computer systems. If searches are performed on any of the retrieval systems, the results can either be printed at the appropriate computer center, downloaded to the OSTI VAX for formation of a subject data base, or downloaded to the user's personal computer (PC) for further processing (see Fig. 5.7). If multiple searches are done and subsets are formed, these subsets can be merged into one, with duplicates eliminated, and then downloaded in a single format to the end user. In view of the tremendous growth in the use of PCs throughout the information retrieval industry, this last feature will undoubtedly be used heavily to aid researchers in forming their own specialized data bases.

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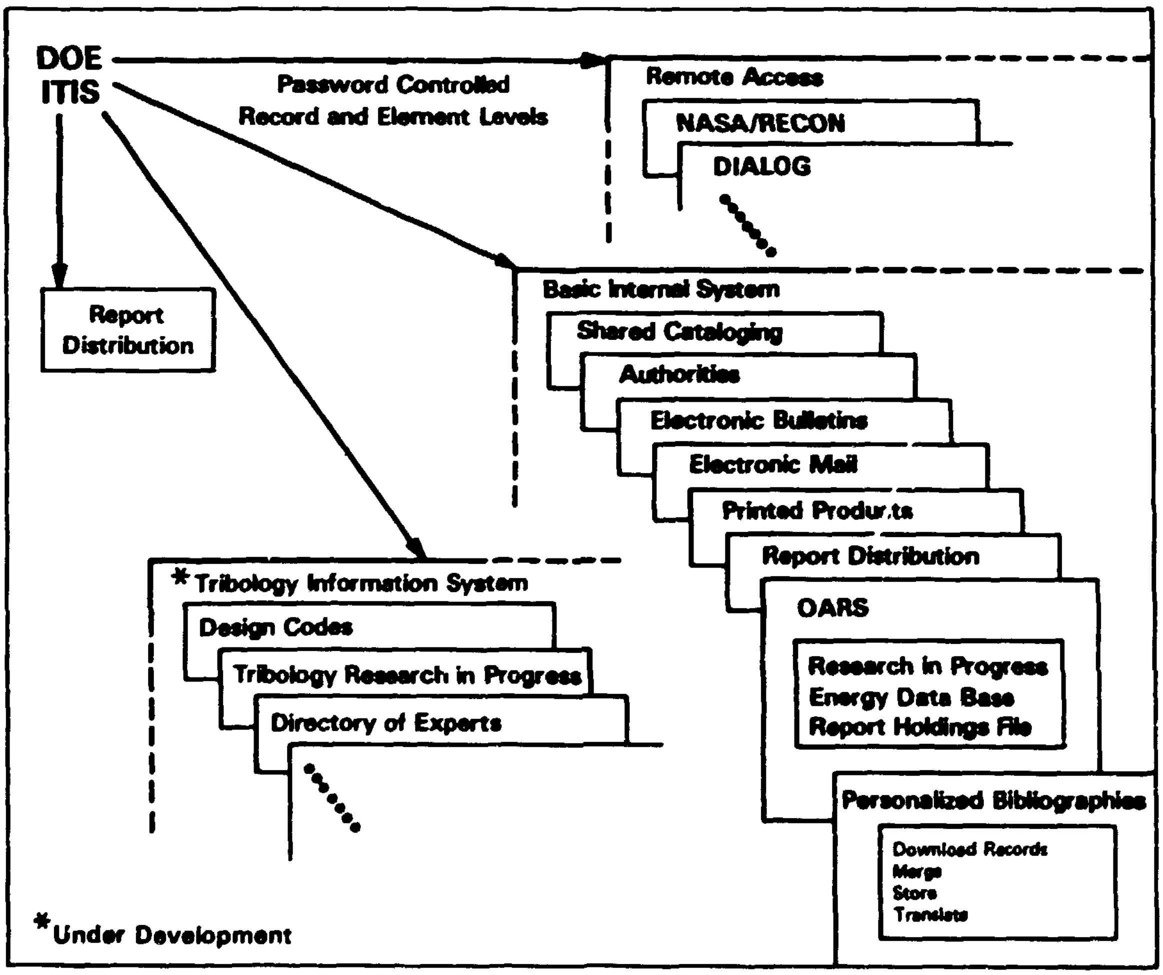

Fig. 5.6. DOE/ITIS provides the user community with many new services, including access to remote retrieval systems and the ability to create personalized bibliographies.

ORNL-DWG 87-9462

INTEGRATED TECHNICAL INFORMATION SYSTEM: INFORMATION FLOW

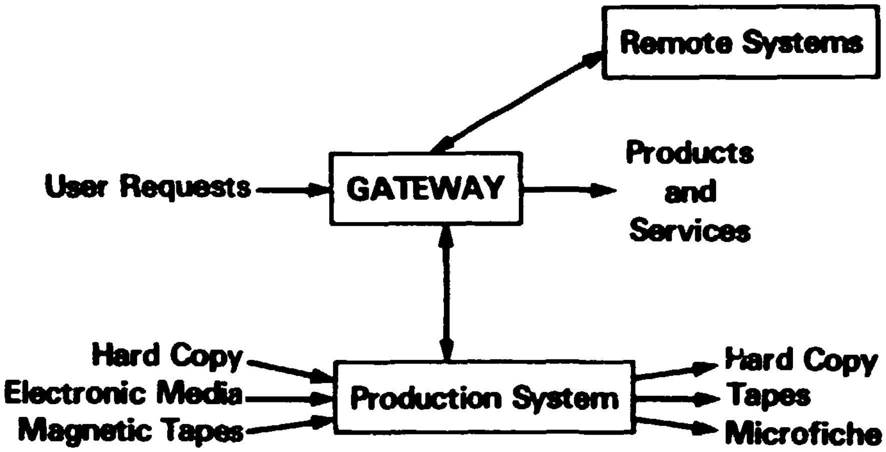

Fig. 5.7. DOE/ITIS gateway allows users to select from a wide range of output products and computer services via on-line requests through a single computer system.

5.2.6 Decision Support Systems In Perspective: An Examination of the Human Success Factors

R. W. Barnes
M. L. Emrich*

The term "decision support system" (DSS) has been applied to a variety of aids ranging from a computerized tool for supporting decision makers to an interactive computer-based information system that helps decision makers use decision models to solve problems.[7] Decision support techniques allow decision makers to access and analyze a wealth of information and data from internal and external sources.[8] Imbedded graphics can aid in the interpretation of a problem by presenting visual representations of relationships, processes, and results.[9] The study reported herein focused on an examination of the characteristics required for an effective DSS in relation to the user's managerial role and style.

A 1984 survey[10] of DSS tools identifies a variety of capabilities. Spreadsheets such as Lotus 1-2-3 and Supercalc, financial planners such as Microplan and Finar, and AI packages such as Lightyear and Expert Ease have been developed to assist decision makers. However, these techniques, as currently developed, are not tailored to the individual's style of thinking, only to the individual's knowledge.

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In practical use, a DSS must cope with a variety of problem-solving styles. Keen[11] advocates a user-driven approach to DSS development, suggesting that the current decision-making methods and the decision-maker's style and mode of analysis are important points to consider before a DSS is defined. DeWaele[12] also cautions against developing a system to fit the problem while ignoring the personal characteristics of the user. Similarly, Schultz and Slevin[13] feel that when designing and implementing a system, user participation is needed to ensure that the system fits the user's method of decision making. Greenfield[14] indicates that the failure of a DSS may be the direct result of unacceptable stress developed when a manager is required to make decisions in a manner foreign to his or her "natural" mode of operation.

For a DSS to be widely accepted and used, the manager should not have to change his or her natural mode of problem solving to accommodate the decision aid. Recent research[15] has focused on classifying decision styles and biases and identifying how each is related to successful performance. The typical classification of problem solving modes varies from highly intuitive "right brain" to primarily analytical "left brain."

Intuitive managers' processes are likely to be speculative in nature—such persons approach a problem in a "what-if" manner. They welcome a wide range of views and alternatives for solving a problem. They may bypass rigorous, analytical planning altogether when faced with novel, intangible problems. Intuitive managers employ problem-solving strategies that are likely to be used in strategic planning at the upper levels of an organization.

Analytical decision makers usually approach problems in a more methodical manner. Managers in this category are interested in orderly and practical solutions that are the result of scientific problem-solving steps, formulas, or procedures. Analytical managers employ problem-solving strategies that are likely to be used in the medium-term or day-to-day operations of an organization.

Researchers differ on how best to accommodate this diversity of styles and management roles within a DSS. Snyders[16] advocates that a DSS should be a collection of "custom-assembled" modules pieced together to meet specific user needs; on the other hand, Huber[17] feels that having a varied and highly flexible system eliminates the need to tailor the DSS to the user's style. However, Wynne[18] states that a DSS should be "personalized" to the user, containing not only quantitative information but also related information derived from behavioral and information science approaches.

Analysis of the literature indicates that the attributes of an effective DSS may be significantly associated with the organizational level of the user (Table 5.1). Strategic planning decisions are generally made at the upper levels of the organization. At the strategic level, DSS styles and capability requirements are likely to be guided by the needs of intuitive managers who are responsible for developing organizational goals and objectives together with methods for achieving them. Because strategic planners use aggregate, summary, and trend data, they will require software that supplies such data. Operational control tasks are usually performed at the junior management level of the organization. Managers at this level are concerned with very short-range decisions involving specific tasks. Their decisions are generally highly structured (often of the type that can be described in a manual or programmed in a computer). Analytical managers tend to thrive at the operational control and procedures level of an organization. Among the DSS tools useful at this organizational level are those that employ highly quantitative management science methodologies such as mathematical programming, queuing models, scheduling models, inventory theory, and process simulation.

Table 5.1. Relationship of DSS capabilities to managerial role, style, and functions

Role	Dominant style	Functions concerned	Appropriate DSS capabilities
Strategic planning	Largely intuitive	Marketing, investments, research, and fiscal	Graphical presentations, trend projection and analysis, correlation analysis, risk analysis, and simulation of alternative decisions
Operational control	Mainly analytical	Credit control, inventory control, production planning/scheduling, quality control, and cost control	Mathematical programming/optimization, inventory modeling, statistical analysis, operations and cost reporting, and scheduling models
Management control	Intuitive and analytical	Budgeting, product evaluation, facilities planning, pricing, and ad hoc data retrieval	Statistical analysis, financial planning models, performance reports, and constrained optimization models

A complement of intuition and analytics is needed by managers who operate at the management control level of an organization. Management control decisions are more short-range than strategic planning decisions (unless involving long-range planning for better use of existing capacity). The primary focus is on current business activities. Decision makers at the managerial control level require both ad hoc and periodic structured reports summarizing data from administrative and operational systems. Other DSS tools appropriate to this level include financial planning systems and cost-benefit analysis aids.

Many applications have been labeled DSS, from electronic spreadsheets to complex strategic planning systems. The use of an electronic computer in the system seems to be the only common element. Each DSS tool, when properly applied, can have valuable use. The DSS tool must not only be appropriate to the managerial function but also to the managerial style concerned. Attention to the personal and interpersonal context within which the system is provided and used (i.e., adapting the DSS to people rather than forcing people to adapt to the system) is a key factor.

5.3 RESEARCH UTILIZATION

Perhaps the most important research utilization activity during FY 1986 was the application of LAN experience gained during a Navy project to the needs at ORNL itself.

Several new initiatives in office automation and communication have resulted from the proliferation of microcomputers at ORNL and their subsequent replacement of terminals, word processors, and typewriters, as well as from the appearance on the market of new hardware and software to link these PCs together to allow very high-speed sharing of files and devices, such as printers and modems.

This local activity parallels efforts in other government agencies to find good answers for similar office environments. Code 182 of the David Taylor Naval Ship R&D Center (DTNSRDC) serves as the development center for the Navy in office automation. A major piece of software produced by ORNL as a result of research sponsored by DTNSRDC is the Technical Office Automation and Communications System (TOFACS), a mini/mainframe-to-terminal application. The emergence of

LANs has led DTNSRDC to attempt to integrate this new networking scheme with their existing software. An initial proposal at DTNSRDC to standardize and recommend an LAN product has singled out the Ungermann-Bass LAN such as that at ORNL.

It is important that ORNL, as well as DTNSRDC and others with an interest in this area, identify the best answers to its office automation and networking needs. In addition, it is important to discover the best ways of connecting these LANs to wide area networks and to solve all the data security problems that arise.

DMG staff have been heavily involved in the prototyping of the TOFACS software. A copy of the software has been installed at ORNL, and attempts to interface it to the Ethernet have shown great promise. As an outgrowth of the TOFACS project, DMG has conducted several additional LAN research projects and has installed 1500 m of Ethernet cabling in Building 4500 North to provide a test bed for LAN research and a network for the staff's microcomputers. More than 50 individual IBM microcomputers, 1 modem, 2 printers, 2 DEC-10 mainframes, 3 microvax's, and an Altos minicomputer have been directly connected to and are accessible over the Ethernet. Electronic mail and a data base for accounting information are available to network users. Controlled access is provided to a wide area network through bridges to a broadband cable.

The Ungermann-Bass networking board is used in over 20 of the microcomputers. A network interface unit that provides multiple interfaces for printers, modems, hosts, and terminals is also used. With the PC board, IBM PC software (suitable for multiple users, including appropriate copyright laws) is being shared among IBM PC users. In effect, our users are all able to use, simultaneously, software that resides on only one hard disk. Software used in this manner is based on the PC disk operating system (DOS) capabilities for file locking to avoid conflicts when more than one user attempts to write to a file. For example, electronic mail, word processing, and data base software can be or are being used on the network in this manner. Great benefits in information transfer have been realized from electronic mail because of the marked improvement effected in communication by eliminating the routine transfer of data by telephone and the delays incurred by missed calls or garbled messages. In addition, the many documents written by the staff which are processed in a central location by support personnel are handled much more quickly now in a much less labor-intensive manner as a result of ease of file transfer, multiuser editing, and remote printers. Our users are also accessing hosts in a terminal emulation mode over the network. Software on the hosts can be used, and file transfers and broadcast messages are possible. Printers connected to a work station or connected to one of the network interface ports can be shared. Laser printers are sufficiently expensive that the ability to share these defrays some of the networking expense.

In addition to the Ungermann-Bass network, which uses the XNS networking protocol, Digital Equipment Corporation's (DEC) DECnet DOS and 3-COM software are also being used on IBM PCs attached to the same Ethernet cable. It has been shown experimentally that these different protocols coexist on the Ethernet with no apparent conflict.

Approximately 30 IBM PCs and compatibles are running DEC's DECnet DOS Version 1.1 software with 3-COM's communications interface board installed. The PCs participate as full DECnet Phase IV nonrouting (end) nodes in the DECnet computer network. The PCs with DECnet DOS are capable of task-to-task communications, remote file access, utilities for network file operations, network command terminal support, and network resource-sharing using the Digital

Network Architecture protocols. With the mini/mainframe computers being predominantly DEC products and the individual workstations being predominantly IBM or compatibles, the demonstrated ability to connect these systems is considered significant. Work is progressing to provide a more user-friendly interface with DEC's ALL-IN-ONE-PC office automation software.

The DMG Ethernet LAN was successfully interconnected to other Ethernet LANs located over the three-plant Oak Ridge complex via Applitek bridges using the intraplant broadband trunk network (see Sect. 5.2.2 for a more detailed discussion).

Connections through bridges and gateways to wide area networks make nationwide communication possible. New technological applications using fiber optics and digitized voice communications and satellite transmission techniques create faster and more reliable long distance networking. These connections will bring previously inaccessible information and communication capability to the individual workstation on LANs such as the one discussed here.

LANs for microcomputers lack the built-in security measures required to create a trusted system suitable for more than a minimum of privacy. A solution should be found to provide security that is rigorous yet does not impact the nature or quality of the existing network software and services. Large computers serving terminals typically control access, authorization, authentication, and accountability through centrally located and elaborate operating systems. This is made possible by the centralized processing and the ability to accommodate a large memory overhead characteristic of such systems and required for elaborate log-in procedures, authentication tables, and audit trails providing accountability.

LANs present special problems in providing the degree of security offered by these larger, centralized systems. Whereas the operating systems for minicomputers and mainframe computers have built-in security, microcomputer operating systems typically do not. In addition, whereas each terminal has its own wired connection to the central processing facilities, LANs use a shared cable over which all data can be accessed. With terminals, tapping a line accesses data flow to and from a single terminal. With LANs, all shared data on the network can be accessed from one tap on the shared cable.

Although many LAN applications do not require high levels of security because of the data classification or the nature or level of threat, almost any network will require some degree of privacy. Typically, the requirements for and degree of privacy are multilevel and selective across the range of information existing on the network as a result of both the nature of and the amount of exposure of the information. Indiscriminate and high-level security measures can be both inappropriate and burdensome to the user.

Research on security and cryptology will be conducted in FY 1987 to identify, select, and prototype data security schemes for LANs and microcomputers to determine effectiveness, ease of implementation, and user acceptance. Emphasis will be on simplicity and portability in multivendor networking environments. DMG staff will also explore the interconnectability of Ethernet LANs with a fiber optic trunk and the connection of the fiber optic trunk to the existing broadband trunk with a media bridge. A third project will explore voice over data communications using the twisted-pair cabling technology.

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6.1 INTRODUCTION

The Decision Systems Research Section (DSRS) is composed of four research groups whose diversity of activity is united by a single, overriding concern: advancing the general state of knowledge and understanding of the decision-making process. The Section deals with a wide variety of specific projects for such sponsors as the Environmental Protection Agency (EPA), the Department of Defense (DOD), the Department of Energy (DOE), and the National Association of Home Builders (NAHB); but these projects must fall within the Section's primary focus on research and development (R&D). DSRS is concerned not only with fulfilling certain concrete tasks but also in generating new ideas, new technologies, and new resources that will enable faster, more-efficient, and higher-quality decisions to be made in any field.

The four groups in DSRS are the Systems Integration Group, headed by H. G. Arnold; the Evaluation Systems and Technology Transfer Group, headed by M. A. Brown; the Information Technologies and Human Systems Group, headed by J. H. Reed; and the Quantitative Methods and Decision Support Group, headed by D. M. Flanagan.

Decision systems research concentrates on how the flow of information, as well as the type of information in the flow, relates to the decision-making process. Subjects for R&D range from totally manual decision systems to ultrasophisticated, fully automated systems. Once the nature of the information flow is better understood, improvements in the time required to produce decisions and in the quality of the decisions can be made.

DSRS groups have mainly been involved in the development of data systems and evaluation methods that improve decision-making processes and increase productivity in large organizations

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that deal with energy, the environment, crisis action planning, and other important problems of national scope. Achieving these research goals requires the use of a multidisciplinary approach, which in FY 1986 included (1) computer systems integration; (2) development of management and decision support systems and software, such as expert systems; (3) environmental policy analysis; (4) quantitative and statistical modeling related to energy supply and use; (5) evaluation of government and utility programs, particularly conservation programs; and (6) technology transfer.

Almost all of the DSRS projects involve joint participation by staff from other Laboratory organizations, such as the Computing and Telecommunications Division, or the assistance of research staff from such institutions as the University of Tennessee, Vanderbilt University, the University of Alabama, and the Georgia Institute of Technology.

During FY 1986, the Section has continued to mature as an R&D organization and is making strides to remain on the cutting edge of decision system theory and practice. DSRS is gradually moving toward establishing itself as a center of excellence in several areas of decision system research. These include open expert systems, including automated knowledge acquisition and machine learning, with particular emphasis on genetic algorithms (see Sect. 6.2.4); experimentation with very high level languages and very high speed processors (see Sect. 6.2.3); decision theory applied to problems in the development of information systems for large public organizations; and energy, environment, and conservation impact issues. Some of these topics have been selected for technical highlights, while others are only briefly mentioned in the research overview for each group (Sects. 6.1.1–6.1.4).

6.1.1 Systems Integration Group

H. G. Arnold*

P. Y. Bengtson	G. R. Hadder	V. Ng
W. B. Dress[†]	K. A. Hake	M. Phifer
J. W. Grubb[‡]	M. L. Johnson	R. M. Rush
R. K. Gryder	R. S. Loffman	F. L. Sexton

The Systems Integration Group has focused on development of computer-aided decision support and data systems and software to connect with the knowledge content of the system. The principal work over the year focused on the areas of data base design, expert system research, and high-speed microprocessor research. Group members provided technical support to the EPA Resource Conservation and Recovery Information System (RCRIS) project (see Sect. 6.2.6 for more details); the Army Civilian Personnel Center (CIVPERCEN) projects; and the Navy Manpower and Training Information System (MAPTIS) workstation R&D project. A small yet significant project was the research into very high level languages and their potential for expert system applications on a Forth language microprocessor (see Sect. 6.2.3). Individual group members also contributed to the Navy mobility fuels availability studies (see Sect. 7.2.3).

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CIVPERCEN has for several years been a major sponsor of the group. Currently, the CIVPERCEN Information Directorate has a mandate to bring the approximately 200 personnel offices throughout the world under an expert system umbrella of data management. ORNL is taking the lead in the design and research needed to integrate the data bases and the expert system so that the individual offices have better decision support tools. ORNL is also providing the technical support and research needed to make the computer systems provided to the distributed offices more user friendly. As part of the total CIVPERCEN effort, six separate data bases are being designed, an analysis tool for screening job applicants is being developed, and an expert system for integrating the analysis tool and the data bases is being designed. The beta (evaluation) test systems are in selected offices.

ORNL is continuing its development of the Information System Planner's Workstation for MAPTIS. This microcomputer-based system integrates on a single computer the several resource management tools now available to planners, giving the user a choice of specific software while retaining menu-like control. Preliminary prototypes were delivered to two training offices this year, and the system will be further refined and integrated in FY 1987 as funding becomes available. ORNL has (1) identified the tasks that an information system planner performs, (2) selected a subset of these tasks which have the potential for immediate implementation, (3) selected and installed commercially available software to aid in the performance of these tasks, and (4) provided templates and documentation of some of the tasks.

6.1.2 Evaluation Systems and Technology Transfer Group

M. A. Brown*

L. G. Berry	J. A. Morell	B. E. Tonn
T. M. Dinan	R. W. Peplies†	T. A. Vineyard
R. T. Goeltz	M. H. Schulte	D. L. White¶
E. A. Hirst	S. A. Snell‡	
M. S. Hubbard	E. J. Soderstrom§	

During FY 1986, the Evaluation Systems Group, previously led by E. A. Hirst, was merged with the Technology Transfer Research Group, previously led by M. A. Brown, to accommodate the one-year off-site assignment of Dr. Hirst to the Puget Sound Power and Light Company.

The major thrust of the evaluation research continues to be detailed quantitative evaluations of government and utility residential energy conservation programs. These evaluations focus on the actual energy savings resulting from the programs and the cost-effectiveness of the programs to participants, to the utility, and to society in general. In large part because of stable and consistent funding from the Bonneville Power Administration (BPA), the group has been able to develop its technical capabilities in an orderly, efficient, and intellectually satisfying manner. Funding from

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DOE's Office of Buildings and Community Systems (OBCS) and Office of State and Local Assistance Programs has added to this base of support, enabling a broadening of the group's focus over the past two years (see Sect. 6.2.4). The group's work is now recognized on a national level as a standard of excellence in evaluating energy conservation programs.

During FY 1986, the following evaluation projects were completed:

1. An analysis of electricity savings one to three years after participation in the BPA Residential Weatherization Program.[1]
2. A report on the use of evaluation results in BPA's conservation modeling process.[2] The report reviews the outputs of various conservation program evaluation studies and compares them with the inputs needed for BPA planning and forecasting models.
3. Comparison of the Princeton Scorekeeping Method of estimating residential space heating with end use data, using consumption data from 319 homes in Hood River.[3]
4. A review of electric utility demand-side programs and integrated resource planning, based on visits to ten utilities.[4]
5. A book on energy efficiency in buildings.[5]
6. An analysis of the role of auditor salesmanship in residential conservation programs.[6]
7. A review and assessment of the BPA conservation, load, and resource modeling process.[7]
8. An analysis of wood use for space heating among electrically heated homes in the Pacific Northwest.[8]
9. An analysis of the methodology used to incorporate price-induced conservation into BPA's planning process.[9]
10. An analysis of utility programs which try to reach markets that traditionally fail to participate in conservation programs (i.e., the low-income, elderly, and multifamily markets).[10]
11. Identification and analysis of barriers to the penetration of residential retrofit measures in the Hood River Project.[11]
12. An analysis of the electricity saved by a residential shared savings program implemented by a utility in several New Jersey and Pennsylvania communities[12] (see Sect. 6.2.5).
13. An analysis of the dynamics of participation and supply of services in the Hood River Conservation Project.[13]

Technology transfer research in the group is concerned both with understanding the process of technology innovation and diffusion and with developing and implementing effective ways to transfer technology, especially from public sector R&D programs. The group provides professional expertise to ORNL and its Office of Technology Applications and undertakes a range of research projects of its own.

During the year, the group's ongoing evaluation of the Energy-Related Inventions Program (ERIP), sponsored by DOE and conducted with the assistance of the National Bureau of Standards, examined the needs of independent inventors and small businesses in commercializing new technologies. Interviews were conducted with 204 ERIP-supported inventors. Of these, 73 experienced successful commercialization, either through direct sales of the ERIP-supported invention, the conclusion of a licensing agreement, a joint venture, or the sale or licensing of a spin-off technology. These 73 inventions generated cumulative sales from 1980 through 1984 of well over $200 million. The return to ERIP grants, in terms of sales of the inventions and their spin-off technologies, was 18 to 1 through 1984. The survey data further indicated that successful ERIP inventors tend to have less formal education, greater experience in small firms and in management positions, greater personal funding of their projects, and more delegation of commercialization responsibilities than their less-successful counterparts.

The group also completed an evaluation of the National Appropriate Technology Assistance Service (NATAS). NATAS is a call-in service that provides information and information-source referrals free of charge to the general public. Two important parts of the evaluation were a client survey concerning the quality of NATAS services and a cost-benefit analysis that compared the value users placed on NATAS services with the cost of providing those services. Both elements of the evaluation were very favorable toward NATAS.

The group continued its involvement with the Technology Transfer and Research Utilization Programs of DOE's OBCS. Program activities included the completion of a technology transfer plan for OBCS outlining the pros and cons of the following five alternative strategies for transferring R&D results: (1) targeting key decision makers, (2) engaging in laboratory/industry cooperative R&D, (3) focusing on innovators and leaders as industrial partners, (4) working through trade and professional associations, and (5) generating end-user demand.[14]

Work began on several innovation case studies. These studies will document and analyze the technology transfer activities leading to the successful commercialization of OBCS R&D products. The group also began compiling and analyzing a data base containing information on all of the technology transfer activities conducted by OBCS during FY 1986.

The group initiated work to support DOE's State Energy Conservation Programs (SECPs) by developing a workbook that was used in the 1986 SECP/EES Program Managers' Conference.[15] In addition to providing worksheets and materials on state energy program planning, the workbook contains abstracts of state energy programs currently operating in each of six issue areas: innovative financing, economic development, information services, standards, cogeneration and resource recovery, and utilities.[15] The authors helped to run workshops on each of these topics at the conference.

Along with these projects, group members continued to pursue research activities in areas related to energy conservation investment decision making, adoption and impact of information technologies, technology transfer as one aspect of cooperative interactions between public institutions and private industry, and innovation diffusion processes.

6.1.3 Information Technologies and Human Systems Group

J. H. Reed*

D. R. Alvic†	H. L. Hwang‡	M. M. Swihart†
P. A. Cerasoli†	R. D. Kraemer†	J. S. Taylor
A. C. Cooper†	W. N. Naegeli†	N. A. Thomas†
M. L. Emrich	C. H. Petrich	L. F. Truett‡
D. M. Evans†	S. L. Purucker	V. L. Vaughn†
H. K. Hardee†	B. L. Shumpert†	A. H. Voelker
E. L. Hillsman		

The Information Technologies and Human Systems Group is concerned with understanding decision making and with designing tools to aid the decision process. The group has ongoing

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‡Dual role.

projects for EPA, DOE, DOD, and the Federal Energy Regulatory Commission. Research is focused on the collection and use of information related to the issues of energy, the environment, and crisis management. Work on several projects has now moved from the conceptual and design stages to the developmental phase.

Significant accomplishments by group members during the year are as follows:

1. Designing and developing a microcomputer-based workstation to aid EPA regulators in assessing groundwater at hazardous waste sites (see Sect. 6.2.2). This workstation is being used by EPA staff to assess the adequacy of the groundwater monitoring and to license waste storage sites.
2. Completion of the Installation Traffic Officer/Military Transportation Management Command (ITO/MTMC) module. This decision support tool provides an automated system to assist the transportation officers at military bases in arranging for the military and commercial movement of cargo and troops in both peacetime and crisis situations for transporting military cargo and troops on commercial vehicles in the United States.
3. Completion of the design of plans for the prototype of the MTMC headquarters' crisis action planning and execution module. This modeling system will be used to make decisions on resource allocation and port management—tasks that have been difficult because of limited automated support for analysts—by providing data base management and mathematical operations research tools to transportation planners at MTMC headquarters and in the field.
4. Completion of an assessment of the aesthetic impacts of low-head hydro developments in the Owens River Basin (see Sect. 2.2.2).
5. Completion of background papers for the Agency for International Development (AID), including one on power supplies in Egypt.
6. Completion of an assessment of the potential for the use of pine charcoal in Madagascar for AID (see Sect. 7.2.1).
7. Organization of an international symposium on "intelligent methodologies" held in cooperation with the University of Tennessee.
8. Providing technical support to the National Governors' Association in integrating states' data needs into the design of a decision support system that both the states and the EPA can use to manage hazardous waste programs under the Resource Conservation and Recovery Act (RCRA).

As the list illustrates, the Information Technologies and Human Systems Group has, over the past year, been heavily involved in the tool-development aspect of decision systems research through R&D of new types and new combinations of software, hardware, and networks. These varied projects have produced valuable information and expertise regarding the decision-making process in general, and this knowledge should have implications beyond the practical application of specific systems for specific problems.

6.1.4 Quantitative Methods and Decision Support Group

D. M. Flanagan*

S. J. Allen	J. L. Hardee	G. E. Liepins
H. Brenner	M. R. Hilliard	L. F. Truett
B. Campbell†	H. L. Hwang	

The Quantitative Methods and Decision Support (QMDS) Group has addressed a variety of problems in the following areas: artificial intelligence (AI) for expert systems, machine learning, operations research, structured analysis, and mathematical and statistical methods. Funding sources for FY 1986 have been DOD, the Energy Information Administration (EIA), and ORNL discretionary research funds.

During FY 1986, the group gained recognition within both ORNL and the general technical community in the areas of error detection and localization, expert systems, and machine learning. These three research areas are expected to grow and become even more important to ORNL and its sponsors. Error detection and correction are particularly important in helping to ensure the quality of data for large data bases. Expert systems are potentially applicable to many problems and can be used as training aids, to assist decision makers, and to suggest solutions. Machine learning is a difficult research area that will have important payoffs with respect to increasing the capabilities (and reducing reprogramming costs) of expert systems and other AI applications such as robotics. The Energy Division's AI work is summarized in Sect. 6.2.4.

During FY 1986, members of the group completed many projects Summaries of these are as follows:

1. The Source Data System (SDS), a new computerized system, collects Navy personnel data in the field offices, edits the data, and provides automated reporting to a central processing site. ORNL evaluated the implementation of SDS for the Naval Military Personnel Command (NMPC) by analyzing the user reaction to the SDS and the impacts of both the course and the new computer system on the organization. The significance of this ORNL research effort is in the approach of evaluating a computer system by questioning the end users.[16]
2. The Total Force Manpower Management System (TFMMS) is a key element in providing a system that will track validated Navy manpower requirements through the planning process to actual authorizations. Through its corporate manpower data base, TFMMS will support a worldwide user community. The TFMMS System Decision Paper I,[17,18] a system design document, is the product of this project. The report is important because, together with the Navy Manpower Information System (NAVMIS) project deliverables, it represents the first comprehensive description of the total manpower process. To produce the report, it was necessary to interview Naval headquarters and field offices in the United States and London, England.

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3. The NAVMIS project for the NMPC is the framework for managing data as a corporate resource, for coordinating the efforts of analysts in building and maintaining data architectures, and for coordinating the efforts of all participants so that a shared data environment can be achieved within the manpower, personnel, and training community. The functional model and logical data model for TFMMS were among the most important contributions during the year.[19]
4. An initial prototype for the Detailer's Assistant Expert System was developed and demonstrated to NMPC sponsors. This expert system assists the Navy detailer staff in making personnel assignments by sifting through the volumes of regulations and required data and creating rules for assignments. The prototype was well received and is the basis for continued prototyping and research in FY 1987 (see Sect. 6.2.4 for futher details).
5. The state of the art in AI applications for Command, Control, and Communications was surveyed for the U.S. Air Force (USAF). As a result, specific implementations of AI technology in the major commands (using the Military Airlift Command as an example) were proposed. The team also designed, prepared, and presented a symposium entitled "AI: The Emerging Technology," to USAF staff and contractors working on the World Wide Military Command and Control System (WWMCCS) modernization program.[20]
6. With the Engineering Physics and Mathematics Division, QMDS staff investigated the current biases in the survey plan for the EIA-826 Data Collection System, which provides data on total electricity sales for the EIA. Improved estimates of the electricity sales and prices were provided for the redesign and update of the survey plan documented in a report to be released in FY 1987.
7. In conjunction with staff from Computing and Telecommunications Division (C&TD), QMDS staff were involved in developing the Scheduling Algorithm for Improving Lift (SAIL) for the Military Sealift Command's system of scheduling deployments using sealift resources. After evaluating alternative algorithms and meeting with university researchers studying the scheduling problem, the staff designed an algorithm and produced a prototype, which was delivered to the sponsor in September. One of the major accomplishments was the influence ORNL had on the organizational structure of the planning community by the citation of (a) numerous problems with the current long-range detailed scheduling methodologies and the proposal of alternatives and (b) discussions that assisted in redefining the interaction between land- and sea-based transportation authorities (see Sect. 6.2.1).
8. The goal of the Marine Corps' Reliability-Centered Maintenance and Reliability and Maintainability programs is to replace a routine maintenance program with one that determines maintenance requirements through an analysis of historical reliability data and consideration of safety, economic, and preparedness factors. ORNL's role in this project is to determine and establish appropriate analytical and human factors techniques to specify optimal maintenance procedures and to suggest the design of a data analysis center.
9. The machine-learning AI project is directed at developing techniques to enable machines to do "passive, unstructured" learning. Initial investigations were centered on genetic algorithms. One system is designed to learn heuristics for scheduling, and the other system discovers rules for navigating a simulated robot. The genetic algorithms were also used as an optimization technique to solve set covering problems. This work is the result of a discretionary funds proposal to M. W. Rosenthal of ORNL (see Sect. 6.2.4).
10. Work began in FY 1986 for the Navy Personnel Research and Development Center (NPRDC). Research was conducted for the Marine Corps to design and recommend a new computerized system to analyze data on enlisted personnel. A draft report was produced.

11. QMDS staff took part in the research of information for the MTMC in support of the Transportation Coordinator Automated Command and Control Information System and produced two draft documents in support of the life-cycle management of the project. Group members also led the development and deployment of the ITO/MTMC Interface Module for the Crisis Action Management System for MTMC and contributed two draft reports on the project. These reports will be published in FY 1987. (More details on the ITO/MTMC project can be found in Sect. 6.1.3.)

6.2 TECHNICAL HIGHLIGHTS

6.2.1 Scheduling Algorithm for Improving Lift

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M. R. Hilliard C. R. Meyers
B. D. Holcomb

The Military Sealift Command is responsible for the movement of military cargo and personnel by ocean carriers during crisis-related operations. These movements are complex because of the scale of operations, the interdependence of the cargos, strategic considerations, and the sudden increase in activity from peacetime levels.

Since April 1985, ORNL has been working with the Military Sealift Command and the Navy Regional Data Automation Center, Washington, in the development of the SAIL algorithm. SAIL is part of a larger effort called the Sealift Strategic Analysis Subsystem, which also includes data gathering, data base management, and user interface modules. SAIL's function is to convert information about cargos, ships, ports, and times into detailed ship routes and cargo schedules.

SAIL must address problems that may include tens of thousands of individual cargos, hundreds of ships, and scores of ports. Each of these entities has several characteristics: cargo is divided into about a dozen types; there are over 15 types of ships; and ports have restrictions on maximum draft, number of berths, and types of facilities. These characteristics, and the military plan itself, combine to form a very large number of constraints on the way in which the cargo can be moved. For example, only certain types of cargo can be placed on certain ships, some ships may not enter some ports, cargo must be loaded in a particular order, and some ports may not be entered before a given date.

Because of unfavorable experience with purely heuristic models, the Navy wanted the SAIL algorithm to use optimization techniques where possible. Because of the size and nonlinearity of the problem, the solution procedure was divided into two segments: resource allocation and detailed scheduling. The former is designed to allocate aggregated cargos to the shipping resources, using the transportation method (a special case of linear programming). The assignments of aggregated cargos to ships which result from the process are used to develop routes for the ships. The second phase, detailed scheduling, assigns specific cargos to the previously routed ships.

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A prototype of the system was delivered to the Navy in September 1986 and is currently being tested. Figure 6.1 shows only one ship route generated by one of these tests. A typical plan would require the production of hundreds of such routes, which would quickly make such maps unreadable.

During the next year, the system will be expanded to honor additional constraints and provide for features such as canal closings, varying port capacity through time, and reducing ship loading to permit entry into shallow ports.

6.2.2 A Decision Support Tool: The Ground Water Workstation

J. H. Reed

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A. Cooper* A. H. Voelker G. W. Westley‡
H. Hardee* W. Naegeli*

DSRS has developed a microcomputer-based decision support tool for EPA's Hazardous Waste Ground Water Task Force (HWGWTF). The tool aids HWGWTF personnel with their evaluation of the adequacy of groundwater monitoring systems and the extent to which groundwater contamination exists at commercial hazardous waste disposal sites. Based on a need assessment, ORNL staff chose off-the-shelf software packages and hardware and integrated these to produce a workstation to satisfy EPA's requirements.

6.2.2.1 Workstation capabilities

The EPA HWGWTF workstation has capabilities that permit the groundwater analyst

- to quickly digitize maps and diagrams supplied by a facility operator;
- to produce overlay maps showing cultural features, waste areas, various types of contours, concentration displays, etc.;
- to generate graphics representing well construction and well lithologies and to use the latter to produce cross-sectional displays;
- to develop statistics describing concentrations of chemicals in samples of well water;
- to calculate flow rates and to display direction of flow on potentiometric contour maps; and
- to model groundwater flow and the transport of pollutants through the groundwater using several models.

The workstation has appropriate data bases and facility, well, and chemical data to support and integrate these capabilities.

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ORNL-DWG 87-9378

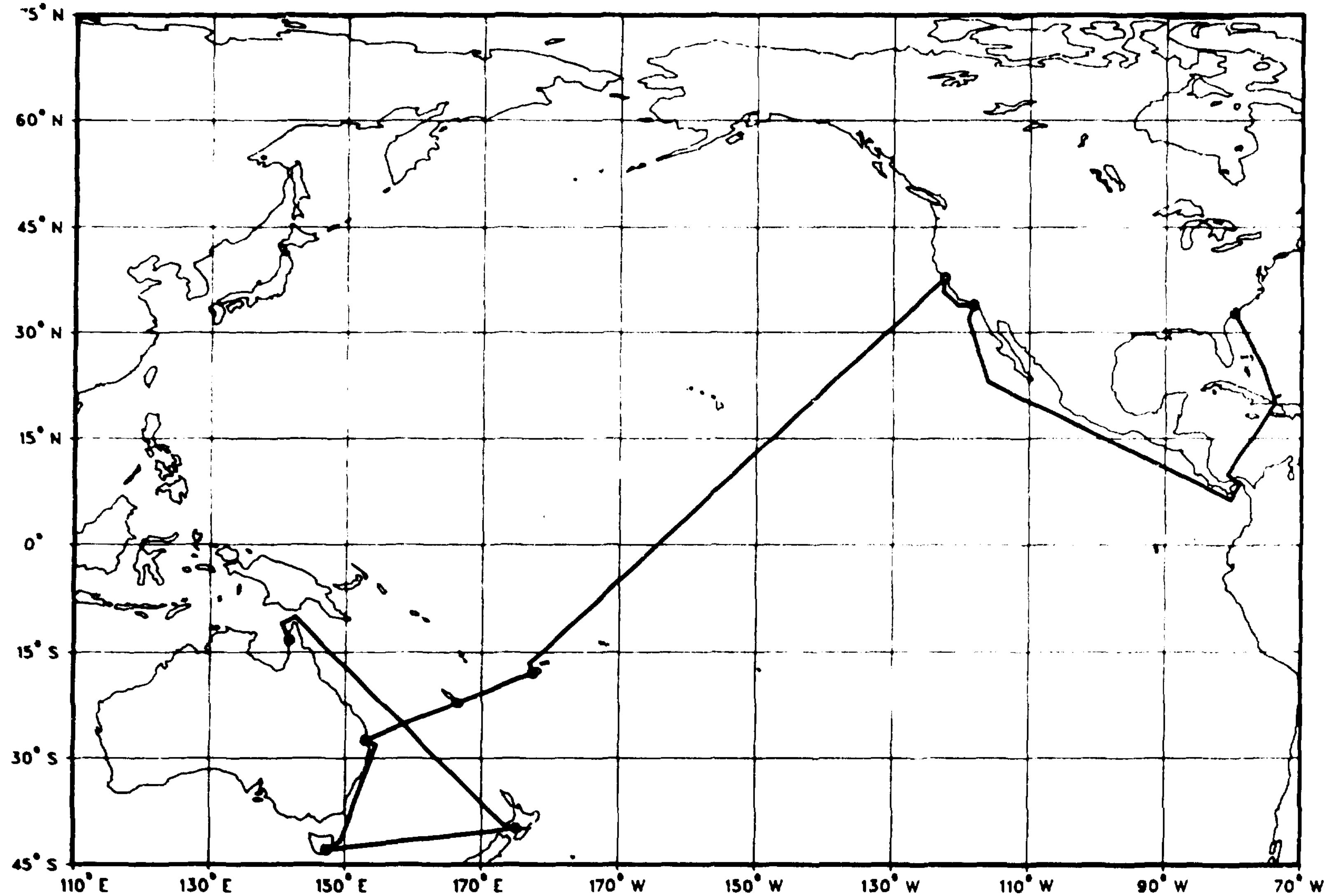

Fig. 6.1. An example of one ship route determined by the model for a hypothetical crisis situation in Australia and New Zealand. The total solution would involve the display of hundreds of such routes.

This application is implemented on an IBM personal computer (PC)/AT. The hardware configuration includes a full 640K memory with an additional 1.5 MB of add-on memory, the IBM enhanced graphics adaptor, a high-resolution Amdek monitor, and a mouse pointing device. Peripheral devices include a printer, a plotter capable of producing large-scale color drawings, removable hard disk storage, and a large digitizing pad. The cost of a workstation including hardware and software is about $25,000.

6.2.2.2 The significance of the workstation

The workstation is a significant development because

- The package integrates a number of tools that have been available only as stand-alone applications.
- It reduces analysis time. For example, the EPA task force has reduced the time required to produce cross sections of waste sites from several weeks to a few hours or perhaps a day.
- It allows data to be analyzed in more ways than was possible by hand. Many of the applications are more user friendly in the PC environment than in their native mainframe environments.
- It provides a uniform method of entering and storing data.
- It permits multiple users (not at the same time) to analyze and reanalyze the same data quickly and efficiently. This capability is important because experts often make different judgments, and additional analyses may help to resolve these differences.
- It permits some limited forms of "what if" analyses.
- It permits the production of professional quality output.

Figure 6.2 illustrates several capabilities of the workstation. The map shows a segment of ORNL. Using a digitizing pad, the street layout was entered into the computer from a site map. The "plus" symbols represent monitoring well locations, and the numbers represent the elevation of the groundwater. The groundwater elevations were obtained from sample data taken at ORNL in September 1986. The groundwater contours were generated from the elevation data by a program on the workstation. Less than 2 h was required to extract the map information, enter the elevation data, generate the contours, and plot the figure.

6.2.2.3 Future developments

Broad interest in the decision support tool has been expressed by both the regulatory community and the regulated community. EPA will transfer the groundwater workstation technology to its ten regions during FY 1987. Numerous states and private firms have expressed interest in the system.

This decision support tool was designed and implemented through a prototyping process. This approach is serving as a model for other work such as that on the RCRIS (see Sect. 6.2.6).

Finally, a number of agencies are interested in tailoring the capabilities of this tool to meet other needs.

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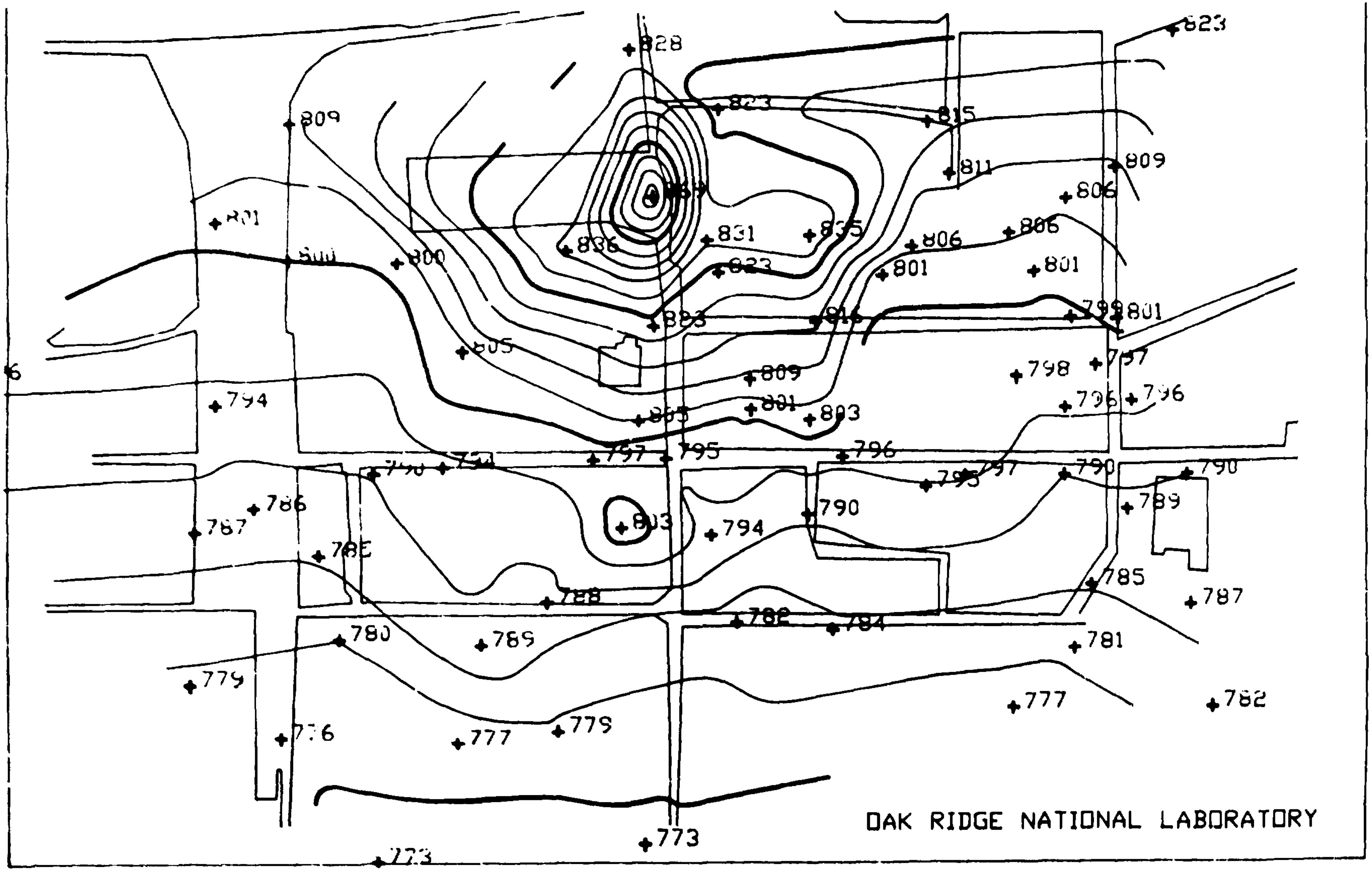

Fig. 6.2. Ground Water contours for a portion of Oak Ridge National Laboratory as drawn by the Ground Water Work Station.

6.2.3 Very High Level Languages and High Speed Symbolic Processing

H. G. Arnold
W. B. Dress*

To determine the potential for developing expert systems and other symbolic processing applications on microcomputers, research was performed in two related areas: (1) a survey of the state of the art of very high level languages (VHLLs) and (2) a novel microprocessor using Forth as its machine language, which confirmed the high-speed potential of high-level machine languages in symbolic processing. It was envisioned that a high-speed expert system could serve as the VHLL for data base management system queries and for other user interfaces in computer applications. Currently, the efficacy of expert systems is limited by the relatively slow processing speed resulting from the complexity of the underlying layers of programming languages.

6.2.3.1 Very high level languages

A survey of the literature and of professionals was conducted to better define the nature of VHLLs to determine if there is any uniformity in the expectations of users and developers and to determine if there is a need for VHLL development to accommodate the advantages offered by high-speed symbolic processing on microcomputers. The immediate conclusions of the survey were that there is no consensus about what a VHLL is or what the criteria are by which one defines a VHLL; however, very similar ideas of what a language should accomplish seem to exist.[21]

Three basic expectations of VHLLs were found consistently in the literature and in interviews. The consensus was that a VHLL should

1. employ declarative statements that eliminate the need for the programmer to specify how the computer is to execute code,
2. allow implicit referencing by which characteristics of a set are associated with each member of the set and need not be specified explicitly, and
3. promote the communicability of knowledge to ease the gap between humans and the computer.

The literature indicates that three other characteristics of a VHLL are also implied by most users or developers. These expectations are that the language should

4. verify correctness by having the language compiler or interpreter check syntax and semantics,
5. accommodate change so that future unforeseen needs can be provided for easily, and
6. have loosely typed data classes to accommodate unexpected formats.

Currently, no language satisfies every VHLL characteristic, and no common understanding of the requirements for a VHLL exists. The requirements of a VHLL are obviously of interest to expert system designers and programmers, and it may well be that the more advanced expert system languages are the forerunners of or even synonymous with VHLLs.

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6.2.3.2 Symbolic processing potential of a Forth engine

To roughly define symbolic processing, we must say that it is not number crunching. Essentially, it is the use of symbols, strings, or typographical notation to accomplish data processing needs. The more common examples of symbolic processing are in the area of expert systems and include the object-oriented programming, list processing, and rule processing techniques that are the underlying attributes of VHLLs. Although the subject of expert systems is important in itself, recognizing that symbolic processing may require a different architecture, different goals, and the consideration of a different end-user community is also important. The new audience for these types of programs is more likely in the executive office and is looking for what we call decision support systems (DSSs)—help in accumulating data and analyzing it to more effectively make decisions rather than do scientific or financial number crunching. Because VHLLs and, by inference, expert systems are anticipated to be key tools in the development of DSSs, exploring the potential for small microcomputers (shoe-box size) to accommodate the systems is of interest.

6.2.3.3 Processing goals

The research described herein has shown that the potential for meeting the Defense Advanced Research Projects Agency (DARPA) goal of 10,000 rules per second[22] may not require the mainframe route. A version of OPS5 on a microcomputer has run as fast as the same widely accepted language will run on popular minicomputers. This microcomputer version of OPS was written in Forth for a 68000 processor desk-top computer.[23] Extrapolations of this initial OPS performance to other environments indicate that the DARPA goals may be not only achievable but even possible now in shoe-box-size computer systems. In October 1985, benchmarks of a Forth chip (a microprocessor using Forth as its machine language) indicated that speeds up to 20 times faster than the microcomputer were possible if the Forth chip could support symbolic processing as well as it supports integer arithmetic. This early set of benchmarks led to the investigation of the potential for symbolic processing speed through other benchmarks, which are summarized here.

6.2.3.4 Benchmarks

While the results are not to be interpreted as the actual speed of symbolic processing, they do offer some idea of the relative speed at which a rule represented by some type of pointer might be processed (as opposed to a rule represented by a string compared with another string). The overall conclusion from Table 6.1 is that the Forth chip should be expected to perform integer operations about 15 times as rapidly as a fast microcomputer and up to 10 times as rapidly as the minicomputer. Table 6.2 shows that, when running empty loops, the chip can keep up with a popular mainframe and that, under some conditions, a special FOR-NEXT feature of the chip can almost keep up with one of the fastest mainframes made. This inability to use the fast machine's vectored architecture illustrates how symbolic processing requires a different approach than scientific computing.

Tables 6.3 and 6.4 show benchmarks in which an attempt was made to add the complexity of VHLL to the execution burden by writing a simple set of list processing (LISP) instructions for the Forth chip and comparing them with the same LISP instructions running on a minicomputer LISP

Table 6.1. Comparison of times to perform one million iterations for selected microcomputers

Computer	Contents of loop		
	Empty loop	16-bit integer store	32-bit integer store
valForth, Atari 800	1:47.30[a]	5:25.19	22:45.00
MVP-Forth, IBM-XT	1:35.10	3:01.50	4:29.80
Forth-32, IBM-XT	1:08.55	4:04.55	4:13.25
MVP-Forth, IBM-AT	0:35.85	1:07.25	1:46.10
Forth-32, IBM-AT	0:24.59	1:23.96	1:25.25
MacForth, MacIntosh	0:19.10	1:06.46	1:06.31
Novix	0:02.50	0:03.22	0:05.81

[a]00:00.0 = minutes : seconds.

Table 6.2. Comparison of times to perform one million iterations for selected mainframes and microcomputers

Computer	Contents of loop		
	Empty loop	16-bit integer store	32-bit integer store
MacForth, MacIntosh	0:19.10[a]	1:06.46	1:06.31
Novix	0:02.50	0:03.22	0:05.81
Forth[b]	0:00.17	0:01.20	0:03.69
Cray-XMP (FORTRAN)	0:00.12		
IBM-3033 (FORTRAN)	0:00.41		
VAX-780 (FORTRAN)	0:02.112		

[a]00:00.0 = minutes : seconds.

[b]Forth algorithm to compare with mainframe times (based on special customized loop similar to optimized compilers).

Table 6.3. Time required for 100,000 LISP iterations

Garbage collection	LISP machine (LMI) (s)	Minicomputer (micro-VAX) (s)	Forth chip (Novix) (s)
No	22	60	
Yes	(15 min?)	95–167	179

Table 6.4. Time required for "Towers of Hanoi" solution for selected minicomputers and microcomputers running OPS and a Forth inference engine

No. of disks	LISP machine (s)	VAX 780 (s)	68000— 8 MHz (s)	68000— 10 MHz (s)	Novix— 6 MHz (s)
5				0.29	0.01
7[a]	22	60	26	1.15	0.06
10				9.25	0.42

[a]Seven disks required 256 rule firings for inference engine.

machine. While the comparisons are not actually made on the same basis because of differing memory management (garbage collection) techniques, the conclusion is that the Forth chip can run LISP about as quickly as a LISP machine or a microcomputer. This does not address the higher speed potential from optimizing the code for the chip nor the tested prototype chip's lower speed in handling strings of bytes 40 times slower than it should because of cell addressing.

Table 6.4 shows a case closer to optimization for the Forth chip: an inference engine for Forth called FORPS.[24] This expert system lacks the VHLL features in that it requires Forth words in its rules but clearly takes advantage of the Forth language in writing an expert system. The benchmarks compared the results of this system running on the chip with those of other computers. The comparison is only incidental, however, because the results present an opportunity to calculate the speed of rule processing in an environment that may be recognizable—the classic "Towers of Hanoi" problem solution. In a goal-directed inference situation, the 68000 processor running Forth achieved speeds close to the 200-rules-per-second capability of mainframe machines (while minicomputers running a VHLL in the form of OPS could only do about 10 rules per second). The Forth chip using the inference engine achieved processing times equivalent to approximately 5000 rules per second in solving the "Towers" problem. It must be noted that there were only four rules and that OPS would handle large rule bases more efficiently; but the fact remains that such processing speeds are possible in small computers when the architecture of the machine, the design of the solution, and the problems are compatible.

6.2.3.5 Conclusion

The basic result of the VHLL survey was the conclusion that a high-level language is not the solution to the computer interface problem. So many high-level languages are now in use that another attempt at simplified user interfaces will have to win acceptance. The answer is perhaps in the area of machine intelligence and pattern recognition rather than in language. With intelligence, the implicitness and inheritance of the VHLL are attributes of the machine rather than of the programmer, thereby making it possible for the programmer to spend less time communicating with the machine.

While it is not evident from these results that the problems of expert systems in particular and AI in general can be solved with Forth-based microcomputers, the benchmarks provide the evidence that the potential is there.[25]

6.2.4 Artificial Intelligence

G. E. Liepins

K. S. Albright*	M. L. Emrich	R. Kroboth§
H. G. Arnold	R. T. Goeltz	S. L. Purucker
L. F. Arrowood†	M. R. Hilliard	J. Ray§
K. R. Carr	E. L. Hillsman	A. R. Sadlowe
S. Das	H. L. Hwang	B. E. Tonn
W. B. Dress‡	D. W. Jones	V. R. Uppuluri¶

The Energy Division is continuing to broaden its AI work. To date, the work either completed, under way, or scheduled includes diverse tasks such as the following:

1. survey of the Air Force WWMCCS Information System (AFWIS) modernization needs,
2. detailer's assistant expert system,
3. budget analyst expert system,
4. Bonneville microwave communication failure analysis expert system,
5. automated acquisition of and reasoning about knowledge (ARK),
6. machine-learning program,
7. utility power systems load model expert system,
8. AI applications to budget preparation, and
9. estimation expert system.

Hardware and software that have been used and are scheduled for use in conjunction with these efforts include the following:

- hardware—two Symbolics 3640s, several MicroVax IIs, a VAX 11/780, Intel Hypercube, and numerous IBM PC/ATs; and
- software—ART; CSF (a classifier code); GENESIS (a genetic algorithm code); M.1; Personnel Consultant Plus; GURU; a variety of microcomputer-based LISPs and Prologs; and additional expert system shells.

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6.2.4.1 AFWIS modernization

Staff from the Energy Division and C&TD surveyed state-of-the-art AI applications for the modernization of the WWMCCS. Key tasks included attending conferences, visiting centers of excellence in AI research for DOD, and proposing specific implementations of AI technology in the major commands.

The results of the study were presented in invited presentations to the sponsor, conferences, and journal articles. The team also designed, prepared, and presented a symposium, entitled "AI: The Emerging Technology," on AI fundamentals to USAF staff and contractors working on the WWMCCS modernization program. This symposium consisted of lectures by ORNL staff, demonstrations of expert systems built by ORNL, and videotapes of discussions of expert system developments by internationally recognized experts. The principal investigators were M. R. Hilliard, M. L. Emrich, H. L. Hwang, and L. F. Arrowood.

6.2.4.2 Detailer's assistant expert system

The detailer's assistant expert system is currently being developed for the NMPC to assist with the placement of Navy personnel. This placement task has historically been done manually, causing substantial stress to novice detailers who are generally required to learn on the job. This stress is aggravated by the ever-changing placement regulations and heavy workload (a workload of 500 assignments per week is not exceptional). The detailer's assistant expert system has been designed to (1) relieve much of the detailer's stress, (2) provide a learning tool for the detailing task, and (3) help ensure timeliness and consistency in assignments. The detailer's expert system complements the development of a network flow assignment program, the network flow approach guarantees cost minimization but cannot adequately deal with more difficult placement issues, such as career advancement. (The relative advantages and disadvantages of the two approaches are summarized in Table 6.5.)

The detailer's assistant expert system has been developed in M.1, a microcomputer-based expert system shell, and is currently expected to be delivered to NMPC on IBM-compatible microcomputers. As of October 1986, the expert system contained about 150 rules, customized user interface, and numerous routines written in C and incorporated into the expert system through the hooks provided within M.1. (About 10,000 lines of C code support the expert system.)

The philosophy guiding the development of the interface was that the necessary data should be provided to the detailers in a format similar to the customary hard copy. Every effort has been made to develop an expert system that is easy to use and accessible to the detailers. Features currently available or planned for the system are as follows:

- custom-designed menu-driven interface,
- data presentation in familiar format,
- explanation capabilities,
- acronym capabilities,
- automatic logging of sessions,
- querying of unusual assignments, and
- reminder functions.

Table 6.5. Comparison of features of expert systems and network programming approaches to personnel assignment

Expert system	Network programming
Emphasis on individual/fine grained/sequential processing	Batch processing
Maintains human element (detailer still required)	Detailer is placed outside the assignment process (except possibly to review)
Decisions explainable in terms familiar to the detailers and enlistees	Decisions determined solely by objective function
Simple input by the detailer can modify the system to reflect changing conditions	Reweighting of the arcs and reestimation of derived parameters must be undertaken by an operations research analyst
Alternate assignments can be suggested for an individual	Difficult to provide alternate assignments for an individual
If machine learning becomes a reality, such a module could be incorporated	All information must be inputted at the outset
Nonoptimizing (satisfying)	Optimizing

To date, the expert system has been targeted at the aviator detailing community only, but intentions are to extend it to other communities. Because NMPC's data systems are not yet finalized, the detailer's expert system does not link with them; however, the capability is available. Also, incorporating machine learning in the expert system is anticipated. The principal investigators are G. E. Liepins and R. Kroboth.

6.2.4.3 Budget analyst expert system

This project is an expert system developed with a microcomputer expert system shell (M.1) that analyzes budget requests for the U.S. Navy. A research prototype has been completed that can analyze a 430-line sample budget for unjustified and anomalous budget requests in 15 min. A human analyst might require 3 1/2 h. The principal staff person on this effort is B. E. Tonn, who works closely with a subcontractor, Applied Management Sciences.

6.2.4.4 Bonneville microwave communication

A feasibility study for BPA is under way to examine the use of an expert system to analyze process power system control center alarms. Research challenges include temporal reasoning and real-time processing. B. E. Tonn, R. T. Goeltz, and S. L. Purucker are working on this task.

6.2.4.5 Automated knowledge acquisition

Research is under way in the area of automated knowledge acquisition. One thrust of this work has been the ARK program. Written in Common LISP, ARK endeavors to engage an expert in dialogue about his or her area of expertise. Experts are allowed to specify relationships between conceptual objects using one of four propositions: causal, accompaniment, associative, and possibly related (e.g., smoking causes cancer). Uncertainty about relationship is expressed in three paradigms: probability, belief, and possibility (e.g., smoking causes cancer with a probability of 0.8).

A multivalued logic has been developed to find possible inconsistencies in the knowledge base created through ARK-expert dialogues. The logic represents a normative method of chaining together relationships that contain different propositions and uncertainty paradigms. An assumption-based truth maintenance system is used to search the knowledge base for inconsistencies. Future work will focus on developing a control language and imbuing ARK with natural language capabilities.

The second thrust of this work has been in the area of uncertainty. A challenge in developing ARK is that the system should not assume how experts cognitively process estimates of uncertainty. Numerous approaches have been proposed in the literature of how to manage uncertainty in expert systems, but no psychological data existed describing to what contexts certain approaches may be suited or whether experts indeed display idiosyncracies in processing uncertainty.

To explore these questions, programs have been written in Common LISP to dynamically survey individuals about uncertainty perceptions related to everyday occurrences and to probe how subjects process the accompanying uncertainty estimates. The results indicate that the heuristics used are context dependent. In one context where conceptual metrics were available to help process uncertainty (questions dealt with the likelihood of doing two activities such as going to a movie and writing a check), individuals used a minimum rule to combine two likelihood estimates. In another context where a conceptual metric was unavailable (questions dealt with the likelihood of a person who possessed personality traits such as honesty and rudeness having a good personality), individuals used a maximum rule or the certainty factor rule to combine two likelihood estimates. Future research will focus on how individuals process uncertainties. Hopefully, these can be represented as natural language text and merged with applicable code into the ARK program. B. E. Tonn, L. F. Arrowood, and R. T. Goeltz are the investigators on this project.

6.2.4.6 Machine-learning program

The machine-learning program is currently focused on research into numeric machine-learning methods. By 1987, that focus is expected to expand to include symbolic learning. Goals include developing automatic techniques for feature determination and extraction and learning transferable rules and heuristics. Current investigations are based primarily on classifier systems and genetic algorithms and are directed at automatic discovery of solutions to job shop scheduling and simulated robot navigation problems. The immediate purpose of both learning experiments is not to develop solution strategies superior to known strategies but rather to demonstrate learning of general heuristics that could be successfully applied to a variety of specific problem settings.

In the simulated robot experiment, the objective is to have the robot acquire the ability to navigate from a start to a goal in an obstacle-filled region. This experiment differs from most robot navigation experiments in that the robot is not preprogrammed with search algorithms and obstacle avoidance rules—such rules and algorithms are precisely what the robot is intended to discover. While the robot is expected to discover initially only simple behavioral rules, the ability for self-adaption in unknown environments should greatly advance robot technology and increase its usefulness. This experiment is currently being conducted on a VAX 11/780 but is expected to be moved to the Intel Hypercube.

The job shop scheduling experiment is already providing some encouraging results. For a specialized problem structure (minimize cumulative signed lateness given the ranking of the run times), the system has been able to discover the correct rules: Place the job with the shortest run time at the top of the queue; place the job with the second-shortest run time next in the queue, etc. The next step is to investigate whether the learning mechanism can automatically develop the concept of "rank" (e.g., "shortest" and "next shortest").

A third experiment is the optimization of problems that are intractable by conventional means: tuning of expert system parameters, sensitivity analysis, or determination of control strategies where classical mathematics and operations research techniques fail. Successes have been reported by the Naval Research Laboratory, which, using genetic algorithms, tuned the AEGIS surveillance expert system and solved the control problem for the positioning of a nonrigid satellite with distributed thrusters. The Energy Division machine-learning program is looking for similarly difficult applications to solve by machine-learning methods. Principal investigators for this project are M. R. Hilliard and G. E. Liepins.

6.2.4.7 Utility power systems load model expert system

Our long-term objective is to prepare a set of tools for power system planning that a utility can use in-house on its own microcomputers. A prototype microcomputer-based AI system is being developed to manage, run, and interpret an alternating-current (AC) load-flow model, with particular emphasis on the problem of adding capacitors to the system to improve the system power factor and thereby reduce transmission losses. The budget for this task is $40,000. We hope to have a prototype ready for debugging by the end of February 1987. Principal staff for this task are S. L. Purucker, J. Ray, S. Das, D. W. Jones, and E. L. Hillsman.

6.2.4.8 AI applications to budget preparation

The preparation of annual budget proposals has historically been a labor-intensive, time-sensitive, and error-prone process for any organization. Rules, guidelines, and regulations for completing the numerous budget submission forms are often hard to understand and implement. The turnaround time for completing such forms may be relatively short, and staff rotations often mean a loss of skilled, knowledgeable personnel. Consequently, resulting proposals may contain inaccurate, inconsistent, and incomplete data.

The application of AI methodologies, particularly expert systems, to aid in the budget preparation process is being explored by Energy Division staff. Project members are designing and constructing a budget preparation system for the U.S. Navy. The expert system assists in the preparation of Base Operating Support (BOS) budget submissions. The BOS budget requires that a large amount of budget data be gathered and detailed on forms. The data reflect the estimated requirements of all field activities. The final budget proposal represents the estimate of what a field activity will need to support its programs for maintaining buildings, providing utilities, managing waste disposal, etc. Before the application of expert system assistance, the budgeting process was performed manually. This budget preparation system was designed to operate as a companion system to a previously developed budget analysis expert system. Principal investigators are M. L. Emrich and H. L. Hwang.

6.2.4.9 Estimation expert system

AI, particularly expert systems, has the potential to be used in several of the U.S. Navy's financial areas. Estimating the resources that are required (including hardware, software, and telecommunications) for large automated data processing projects is one such area. Determining time, cost, equipment, and personnel needs for a given Navy project has historically been a manual task.

Skilled Navy estimators are long on tenure and nearing retirement. Their replacements may not be sufficiently experienced to make accurate estimating decisions. Applying expert systems methodologies to the problem-solving tasks faced by Navy estimators has been an Energy Division research effort.

The the coding of an expert's knowledge into a computer program is time consuming; however, the acquisition of necessary knowledge has traditionally hindered the construction of an expert system. A variety of data gathering, interviewing, and verification techniques may be required to acquire the information needed for knowledge-base construction. The project staff are in the process of applying a variety of social science techniques to the challenges of acquiring the appropriate knowledge for system construction. Principal investigators for this project are M. L. Emrich, A. R. Sadlowe, L. F. Arrowood, and K. S. Albright.

In addition to the work outlined above, preliminary work has begun on a candidate evaluation expert system for the Army Civilian Personnel agency.

6.2.5 Residential Energy Conservation Action Program

M. A. Brown and D. L. White

The purpose of this work is to evaluate the effectiveness of a novel residential energy conservation shared savings program—the Residential Energy Conservation Action Program (RECAP)—conducted in four communities in New Jersey and Pennsylvania. The program is administered by the General Public Utilities (GPU) Corporation through contracts with energy services companies. These contractors install energy retrofit measures in homes of all-electric GPU customers and are repaid by the utility for their work on the basis of measured electricity savings.

This discussion focuses primarily on the electricity savings attributable to RECAP. Customer satisfaction with the program, comfort benefits, electric peak load controls, and the displacement of alternative heating fuels are also assessed. Furthermore, attention is given to contractor-, community-, and household-specific influences on electricity savings. This discussion builds upon an earlier evaluation of the process of implementing RECAP.[26,27]

6.2.5.1 Data and methodology

This evaluation examines preretrofit and postretrofit electricity consumption for program participants and compares the results with the electricity consumption of matched control group communities. To correct for variations in heating degree days over time and across communities, a weather normalization technique is employed. Survey data from program participants are also analyzed. The evaluation consists of two phases: (1) estimating electricity savings in each of the four RECAP communities and (2) explaining the savings by analyzing survey data.

6.2.5.2 Findings

Averaging across all four RECAP communities, participating households conserved approximately 1600 kWh/year after retrofit, representing a 7.6% decrease in consumption. Because the control group's electricity use over the same three-year period also decreased, the net savings (i.e., that which is attributable to RECAP) is reduced to 1273 kWh/year, or 6.6% of the preretrofit level of consumption. As Fig. 6.3 illustrates, the estimates of total and net savings differ markedly across the four RECAP communities.

There is only a weak association between electricity savings and installation costs, indicating that energy savings are not entirely predetermined by the cost of the retrofit work. The most expensive RECAP project (in York, Pennsylvania) has the greatest total and net savings. On the other hand, the least expensive RECAP project (i.e., Covered Bridge, New Jersey) experienced twice the savings of the Leisure Village, New Jersey, project, for one-half the cost per retrofit.

Multiple regression analysis indicates that greater savings from participation in RECAP are associated with certain conditions at the time of retrofit (i.e., higher levels of electricity consumption, larger households, and newer homes); certain changes since retrofit (e.g., fewer household members, decreased use of appliances, addition of a new source of nonelectric heat, and lower winter thermostat settings); and satisfaction with the program.

In addition, households treated by one of the contractors saved less. The lack of selectivity in choosing households to participate in RECAP distinguishes this contractor from other contractors and may account for this pattern. The two New Jersey projects (which were retirement communities in contrast to the two heterogeneous Pennsylvania areas) also saved more. Altogether, the multiple regression models are able to explain 27% of the variation in kilowatt-hour savings and 16% of the variation in percent kilowatt-hour savings.

Survey data were examined to assess levels of satisfaction with the program. Overall, participants perceived their experiences with RECAP as positive, and a vast majority of them would recommend RECAP to others. Participants also reported that the program increased their comfort levels and reduced drafts.

Also examined were the impacts on program savings of three variables:

- changes in thermostat settings,
- override of the water heater control, and
- changes in the use of supplemental fuels.

It was found that few participants changed their winter thermostat settings after RECAP, suggesting the absence of any "takeback" of potential savings through increased comfort. On the other hand, the water heater control—a device installed in all participating homes—was overridden

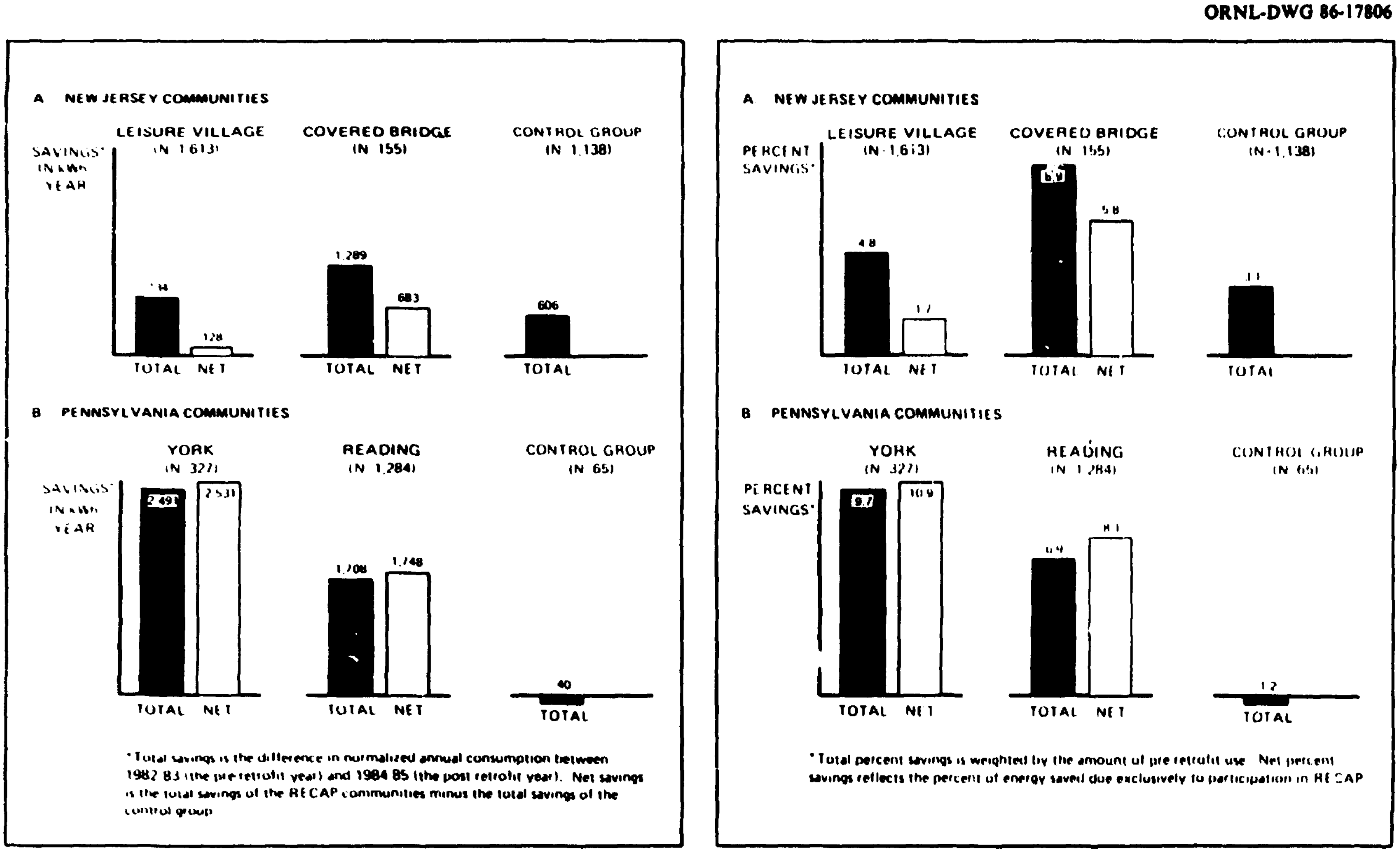

Fig. 6.3. Energy savings in kilowatt-hours per year and energy savings as a percentage of preretrofit use.

at least four times each week by 21% of the participants in one of the RECAP communities, suggesting that the anticipated load benefits of the program may not fully materialize. In one of the two communities in which nonelectric heating fuels are allowed, a small displacement of wood and kerosene use by electricity appears to have occurred—a trend that slightly reduced the program's actual electricity savings. However, the overall impact of these behavioral factors is minimal.[26]

The transferability of RECAP to other utilities and locales depends upon the value of kilowatt-hour and kilowatt savings in these areas and the costs of obtaining these through retrofit measures. As with most energy conservation and load management programs, RECAP would appear to be most useful for utilities with high marginal fuel costs and projected near-term energy supply shortfalls. Residential shared savings programs such as RECAP would also appear to be most desirable when a utility needs to achieve (1) improved customer relations; (2) high penetration rates of residential retrofit measures; (3) significant energy savings through weatherization of high-energy-consuming residences; or (4) energy savings in retirement communities or other developments where housing stock is uniform and homeowner motivation is low (e.g., condominium/townhouse developments).

6.2.6 EPA Office of Solid Waste and Emergency Response

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The EPA Office of Solid Waste and Emergency Response (OSWER) has responsibility for the national regulation of hazardous waste mandated by RCRA. One of the primary goals of RCRA is to provide a "cradle-to-grave" accounting of hazardous wastes from generation, through transportation, treatment, and storage, to ultimate destruction or disposal. ORNL is assisting OSWER with the modernization of the information systems used in the administration of the RCRA program. EPA has asked ORNL to do this work because the Laboratory has extensive experience in helping government agencies convert from obsolete, centralized systems to distributed systems that use fourth-generation data base management software and microcomputer workstations.

ORNL has now completed work on the concept for the new system, known as RCRIS. As shown in Fig. 6.4, the new system distributes data base storage and information processing to various types of computer equipment located at the EPA regional offices. The next level of distributed processing involves the state systems that would be linked to the regional offices. This is a radical change from the concept used by the current system, which employs one central processing unit for all data storage and processing.

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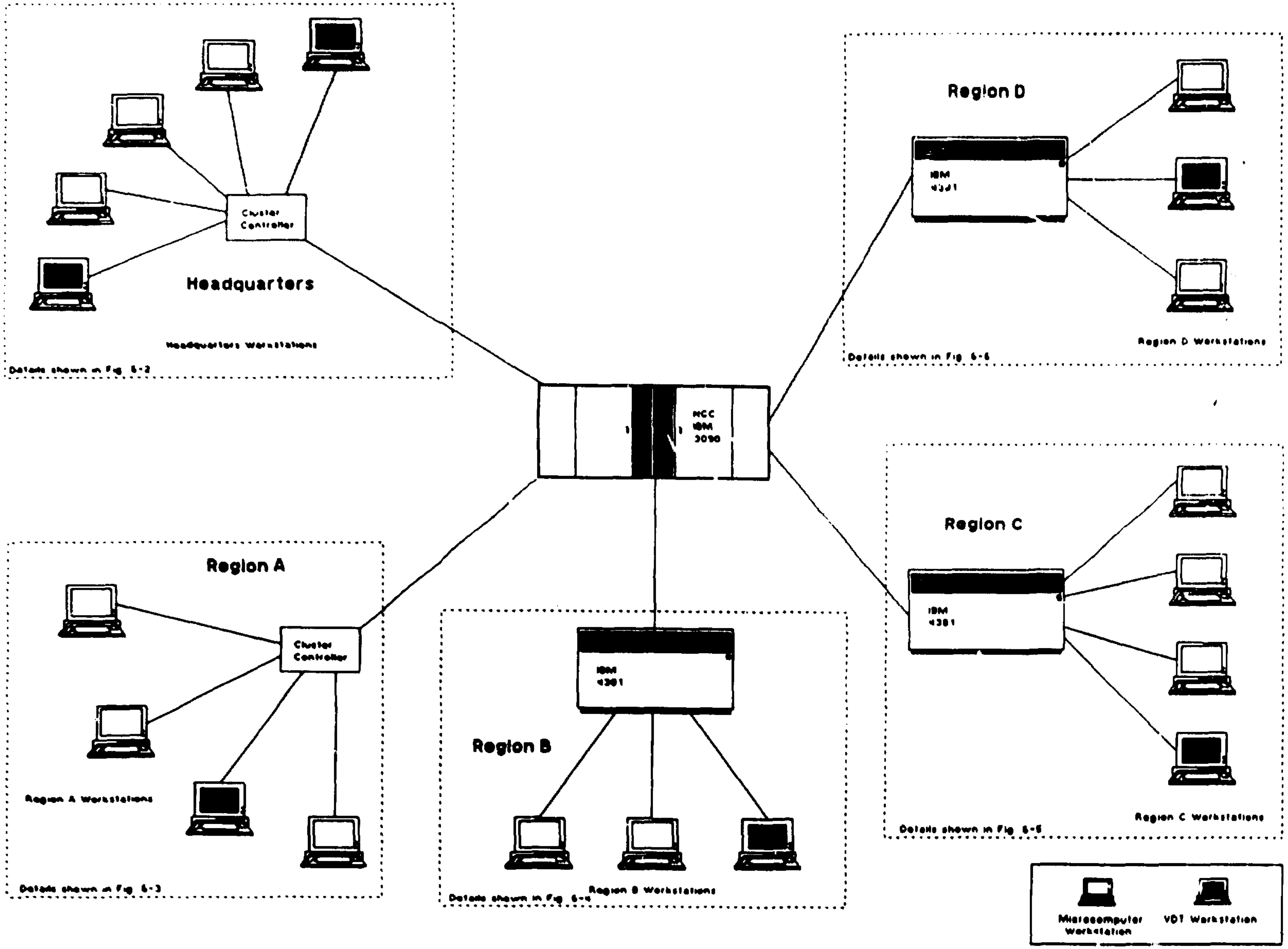

Fig. 6.4. An illustration of the RCRIS distributed processing concept applied at the EPA regional office level. A similar representation would show the state office level linked to the regions.

Input from EPA regional and state personnel involved in implementing the RCRA program resulted in the identification of a key design principle, called the two-domain concept, that allows for division of the data into implementer and oversight domains. The two-domain concept allows the states to take full responsibility for the data associated with the RCRA program in their domain while keeping separate the data that EPA requires for oversight of program consistency and effectiveness.

The work plan for the next step in the development of RCRIS will be undertaken using rapid-prototyping methodology. This technique uses a series of evolutionary prototypes to develop agreement on the functions to be provided by the system, followed by a tuning step to obtain the required performance and consistency. Use of rapid prototyping has been shown to reduce system development efforts from as much as two to seven times over the conventional functional description/detailed design process.

The work plan calls for dividing the system into modules that can be worked on concurrently. The first three modules will address facility/handler identification, permit/closure application processing, and compliance monitoring and enforcement. Completion of these three modules, as well as the data base administration module, will result in enough system components to enable conducting a test in one EPA region during the fall of 1987. Completion of the remainder of the system is expected by the end of 1988.

ORNL is also assisting OSWER with the development of a prototype workstation that will assist EPA in coping with the ever-increasing amount of groundwater monitoring data for land disposal facilities regulated under the RCRA program (see Sect. 6.2.2). This work is based on ORNL's previous experience in the development of workstations for the Navy Information Systems Management Division for use in planning manpower, personnel, and training requirements.

As a result of the work leading to the concept for RCRIS, OSWER has asked ORNL to assist in establishing the charter for an OSWER-wide data administration function. This new OSWER group will be charged with formulating a program to improve data quality for all OSWER information systems and will set procedures and goals for defining data elements, measuring data quality, and controlling the process of changing data bases. The group will also act as a consultant in assigning responsibility and measuring contributions toward improving data quality. The establishment of a data administration function is especially crucial now because of EPA's plans to transfer additional responsibility for environmental programs (such as RCRA) from federal to state custody.

6.3 RESEARCH UTILIZATION

6.3.1 Systems Integration Group

The sponsors are the principal users of the research performed in the Systems Integration Group. However, there has been significant interaction with private firms in the course of problem solving on the Burroughs computers and in the investigation of the very high level languages and the Novix chip. ORNL staff recommended architectural changes to the production version of the Novix chip due out in December 1986, based on our evaluation of the beta version (see Sect. 6.2.3). We are now collaborating informally with an ad hoc group formed as a result of our Novix contacts on the use of neural networks in machine learning and data storage.

6.3.2 Evaluation Systems and Technology Transfer Group

Much of the evaluation research in the section was used by utilities who sponsored or cosponsored the work. These sponsors have used our research to assist in the design of their demand-side program planning. Others who plan and implement energy conservation programs—such as state energy offices, utilities, and state public service commissions—are kept abreast of ORNL evaluation research through presentations at conferences and widespread distribution of ORNL reports. Results of the evaluation work are disseminated within the research community through publications in the open, refereed literature.

Technology transfer research findings within DSRS have been used by DOE sponsors to improve the effectiveness of their technology transfer activities. The Section also manages the technology transfer program of DOE's OBCS and in this capacity has succeeded in stimulating the use of OBCS R&D by researchers, educators, building trade and professional associations, and practitioners in the buildings industry. Two institutes, one for engineering and one for architecture, have been held annually to highlight OBCS research and to encourage the inclusion of energy subjects in university curricula. Several decision tools have been developed and successfully transferred to users as a means of easily incorporating energy efficiency in the design of buildings and the choice of building equipment.

6.3.3 Information Technologies and Human Systems Group

Although the EPA groundwater workstation is in the developmental stage, it is already being used by and receiving attention from the EPA regional offices. EPA has used the workstation for several site investigations and in negotiations with site owners. Output from the workstation has been used to brief congressmen about sites in their district. EPA will place workstations in its regions in FY 1987; the state of California is seeking funds to purchase workstations.

6.3.4 Quantitative Methods and Decision Support Group

The system decision paper[18] for the Total Force Manpower Management System (TFMMS) and the functional model[19] for TFMMS are both being used for the Naval postgraduate school courses in manpower analysis, in addition to being used by other projects at ORNL. Staff members have had numerous requests for papers, including all of the AI articles written by QMDS staff, especially the detailer assistant expert system and the genetic algorithm research, and work in error detection and localization. Professional societies have also requested presentations on those topics. Presentations requested by sponsors have included overviews of AI at ORNL for such organizations as the Army Information Systems Engineering Command, the Federal Emergency Management Agency, the Army Institute for Research in Management Information and Computer Science, and the Navy Training Systems Center. The symposium entitled "AI: The Emerging Technology" was presented to the WWMCCS Modernization Program Office to transfer research knowledge to the USAF and its subcontracting staff.

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7. Integrated Programs

T. J. Wilbanks

S. B. Wright   C. S. Massingill

7.1 INTRODUCTION

The Integrated Programs part of the Energy Division continued its evolution during FY 1986 with the transfer of the Technology Transfer Research Group to the Decision Systems Research Section, where it was integrated with the Evaluation Group (Chap. 6). Meanwhile, the Division's work in International Applications continued to expand, and social science development activities during the year were focused on the development of ideas about a generic research program on technology utilization. Other programs continuing from previous years were (1) Emergency Preparedness Studies, coordinated by C. V. Chester; (2) Evaluation Program Coordination, headed by E. A. Hirst; (3) Mobility Fuels and Transportation Coordination, led by R. M. Davis; and (4) the Technology Transfer Program, coordinated by M. A. Brown. In addition, the Division's Planning and Special Studies Group, consisting of A. M. Perry, G. Samuels, and T. J. Wilbanks, continued to contribute to Division planning and program development, to assist with high-priority projects, and to conduct research and assessment efforts related to emphases in the Division's Long-Range Plan.

7.1.1 International Applications

T. J. Wilbanks

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D. J. Bjornstad	D. W. Jones	J. W. Ranney[¶]
R. A. Cantor	H. G. Jones[†]	G. Samuels
T. R. Curlee	S. I. Kaplan	R. B. Shelton
S. Das	F. Kertesz[§]	G. G. Stevenson
A. E. Ekkebus	R. P. Krishnan*	P. J. Sullivan
D. M. Eissenberg*	C. S. Massingill	D. A. Trumble
J. Finnell[†]	R. D. Perlack	A. F. Turhollow
D. L. Greene	C. H. Petrich	D. P. Vogt
A. R. Hawthorne[‡]	J. J. Pinajian	S. B. Wright
L. J. Hill		

In FY 1986, the Division's program of analysis and technical assistance related to the energy needs of developing countries, supported by the U.S. Agency for International Development (AID), continued to grow and diversify. Current programs include two major responsibilities for AID's Office of Energy: (1) energy planning and policy development assistance and (2) assistance related to renewable energy applications and energy for rural areas. In both cases, interagency agreements between AID and the Department of Energy (DOE) make it possible for field missions and other AID offices to get access to ORNL resources, in addition to the Office of Energy itself.

The Energy Planning and Policy Development (EPPD) Program was originally focused on national energy planning and institution-building,[1] together with technical assistance to missions with energy project design, implementation, and evaluation. This type of work continued in FY 1986 with technical assistance to Haiti (Sects. 3.1.2 and 3.2.1); project evaluations in Bangladesh, Morocco, Ecuador, and the Philippines; project design assistance to missions in India and Pakistan; and further attention to the general experience with national energy planning to date.[2]

Based on ORNL analyses of the energy problems of developing countries in the 1980s,[1] however, the program has been shifted away from comprehensive energy planning by government planning units. The current focus is on three specific high-priority issues for institutions that make energy decisions in AID-assisted countries:

1. Power system planning. From the perspective of most developing countries in the 1980s, the number one energy problem is capital requirements for power system expansion. Complementing other Office of Energy activities to encourage the rationalization of electricity prices and increased attention to private sector roles, this program emphasizes the potential for improving system efficiency through least-cost planning, considering efficiency improvement possibilities throughout the power supply and use system.

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2. Energy price reform. From the perspective of most development assistance agencies in the 1980s, the number one energy *policy* problem in many developing countries is energy prices. EPPD provides technical assistance to AID missions in policy dialogues about energy price reform and to AID-assisted countries in moving toward rational energy prices. The special emphasis is on strategies for implementing price reform without counterproductive economic or political instability.
3. Household fuel alternatives. The most serious energy problem for the *poor* in AID-assisted countries is assuring adequate and affordable household fuels. EPPD complements AID forestry programs by exploring the potential of substitutes for wood and wood charcoal as household fuels and the potential to improve the efficiency of using wood as a fuel (see Sect. 7.2.1).

In addition, the EPPD program continued its assistance to the Office of Energy in improving decision support systems for program managers, ranging from project management software development to office automation, telecommunication, and technical information assistance (see Sect. 7.2.2). The Energy Division also continued its attention to energy use in the transportation sector of developing countries (see Sect. 3.1.3) and implemented an energy policy research program, supporting small research projects on subjects of interest to AID, which awarded six research contracts following a request for proposals from the research community.

The second ORNL program, in renewable energy applications and energy for rural areas, emphasized a reassessment of lessons learned from a dozen years of experience with renewable energy applications in developing countries, resulting in a draft interim report for discussion within AID. The program also began the development of a strategy statement on small power systems for the energy needs of rural areas and continued support for Office of Energy activities related to energy for agriculture, particularly energy for water lifting.

7.1.2 Emergency Preparedness

C. V. Chester
J. A. Coleman

The Division continued its diversified multidisciplinary effort in emergency preparedness in FY 1986, the accomplishments of which are reported in the preceding chapters of this report. Since the late 1970s, this program has expanded enormously from its origins in a small civil defense research activity. It now includes a major analytical support responsibility for the Federal Emergency Management Agency (FEMA) and has successfully integrated the contributions of social scientists, engineers, health and environmental scientists, and others in addressing a wide variety of possible emergencies: nuclear war, nuclear winter, energy transportation system disruptions, electromagnetic pulse, hydroelectric dam failures, and others. For example, supported by FEMA, in FY 1986, the Division completed its assessments of the state of the art in understanding several fundamental issues in emergency preparedness, such as the technological and institutional feasibility of preparedness measures (Sect. 2.1.7; also see Sect. 2.1.6), and continued to improve FEMA's capabilities for modeling regional impacts of emergencies and planning emergency responses (Sect. 3.1.2). In addition, the Division followed up its assessment of the postdisaster recovery experience with research on conditions under which markets return to effective operation following a cataclysm (Sects. 3.1.2 and 2.1.4.3). Other emergency preparedness activities included work on emergency response capabilities for electric power systems and pipelines (Sects. 2.1.7 and 2.1.6); warning and evacuation capabilities (Sect. 2.1.6); radiological emergency preparedness (Sect. 2.1.7.1); nuclear winter (Sect. 2.1.7.3); dam safety (Sect. 3.1.4); electromagnetic pulse (Sect. 4.2.7; also see 4.1.4); transportation system management during emergencies, including data system applications (Sects. 3.1.3, 6.2.1, 6.1.3, and 7.2.3); and technology alternatives for coping with emergency conditions.

7.1.3 Social Science Development

T. J. Wilbanks

R. B. Honea	J. H. Sorensen
R. B. Shelton	H. E. Zittel

During FY 1986, along with the usual activities related to staff recruitment, professional development, and quality assurance, this program developed a proposal for a two-year effort to determine the feasibility of a center at ORNL to conduct research on technology utilization. The effort will address questions of technology acceptance, both by host communities and society at large, and technology transfer. Proposed activities include the preparation of white papers on generic technology utilization issues, the acquisition of data bases and resource materials, an exploration of linkages with other research centers, interactions with ongoing ORNL programs, and a survey of the environment for financial support for technology utilization research.

7.1.4 Mobility Fuels and Transportation Studies

R. M. Davis
A. C. Phillips

S. M. Chin	R. Kramer	F. Southworth
S. Das	R. Lee	T. A. Vineyard
G. R. Hadder	B. E. Peterson	

The Division's research on liquid fuels and transportation issues grew significantly during the year. Liquid fuel availability has been an issue for economic stability and national security in the United States since 1973; in the 1980s, fuel availability remains a key component of military preparedness and readiness. The Office of Naval Technology, the Air Force Wright-Patterson Aeronautical Laboratories, and the Army Fuels and Lubrication Office are supporting a variety of research at ORNL to investigate the availability of traditional military fuels as well as the technical and economic feasibility of developing new substitute fuels. In FY 1986, Energy Division staff continued a major effort for the Navy to develop and test analytical approaches for assessing world oil and petroleum product market trends. The Navy Mobility Fuel Forecasting System is being tested for use in evaluating strategies for increasing the supply of liquid military fuels under normal and emergency market conditions (Sect. 7.2.3). In related work, ORNL continued its management of the alternative fuels program, including a major demonstration of the use of methanol in fleet vehicles, co-funded by DOE and the Army (Sect. 3.1.3). Work was begun in the Chemistry Division to evaluate and characterize potential high-density liquid fuels required for high-performance military aircraft and space applications.

Major programs also continued in transportation and logistics research, primarily in support of Department of Defense (DOD) agencies. During FY 1986, the Division continued its work for the U.S. Army Forces Command by adding data on ports, bridges, tunnels, and airports to the highway network, along with testing routing algorithms and graphics software important to military and civilian operations. The analytical capability developed in these programs directly supports the programmatic requirements of DOE, the Department of Transportation, and other civilian agencies in analyzing the movement of nuclear materials, hazardous wastes, and military systems.

7.1.5 Special Studies

The Planning and Special Studies Group also helped to address other issues that arose during FY 1985. For example, A. M. Perry continued his examination of possible environmental effects of further releases of chlorocarbons in the earth's atmosphere (Sect. 7.2.4), and T. J. Wilbanks considered the prospects of synthetic fuels in the United States[3] and future energy and technological crises in the Sunbelt.[4]

7.2 TECHNICAL HIGHLIGHTS

7.2.1 Improved Household Fuel Alternatives for Developing Countries

C. H. Petrich
R. B. Shelton

W. F. Barron
M. A. Brown
R. A. Cantor
G. G. Stevenson
T. Willson*

For many low-income people in developing countries, traditional fuel supplies are dwindling, especially in wood-scarce areas. Meanwhile, commercial fuels rose sharply in price during the 1970s and remain expensive by local standards. Commonly, the result is either that a family must spend considerably more of its money and time to acquire household fuels or that it must reduce its fuel use, generally by reducing energy services because efficiency improvements require levels of capital investment (i.e., purchases of more efficient cooking stoves) that are impossible for many poor families. In either case, the quality of life falls.

One approach to solving this problem is to encourage afforestation through energy plantations, agroforestry, or social forestry; but this approach has thus far been unable to keep up with the growing problem, much less reduce it. A complementary approach is to find substitutes for

*JDS Group, Inc.

traditional fuels, especially wood and wood charcoal, which are acceptable and affordable. A third approach is to find cheaper and more accessible ways to increase the efficiency of using wood as a fuel (e.g., by increasing the efficiency of cook stoves or wood charcoal production). A fourth possibility is to find alternative sources of traditional fuels (e.g., supplies from other source areas). AID's Office of Energy is exploring all of these potentials except the first, which is addressed by AID's Office of Forestry.

During FY 1986, the Energy Division completed a prototype assessment of the potential for coal or lignite briquettes to substitute for wood charcoal in wood-scarce countries that have coal resources (Sect. 3.1.2). Conducted in Haiti but also intended as a model for subsequent studies elsewhere,[5] this assessment combined information about domestic lignite resources and briquette production technologies with research on markets, institutional factors, and health impacts to evaluate the commercial attractiveness of lignite briquettes for residential, commercial, and small industrial markets in the Port-au-Prince area. Because wood and wood charcoal prices in Haiti are astonishingly low, especially for a desperately wood-scarce country (mainly because so much of the wood is cut to clear land rather than to sell as a valued product), and the energy value of Haitian lignite is also low (2500 to 3000 kcal/kg), the study concluded that briquettes from local lignite are not likely to be competitive in Haiti under current conditions (see Table 7.1). Briquettes manufactured from imported high-volatile coal are more promising, though still only marginally competitive. If production costs can be lowered, however, by such strategies as using pyrolysis equipment already manufactured but currently moth-balled (as at least one U.S. entrepreneur believes), coal briquettes will become an attractive alternative even with wood charcoal prices very low. The Division also began an assessment of markets for lignite briquettes in Pakistan, where wood fuel prices are higher than in Haiti and indigenous technical capabilities are substantial (Sect. 3.1.2).

In addition, in collaboration with the World Bank, ORNL organized and led AID's contribution to joint teams to evaluate household fuel options in Zaire and Madagascar. For example, a joint World Bank–ORNL team evaluated the feasibility of using biomass residues from a large pine plantation in Madagascar to produce wood charcoal for the rapidly growing Antananarivo cooking fuel market. Such an alternative source of wood fuels, it was believed, would help to reduce

Table 7.1. Estimated economic attractiveness of producing and selling coal/lignite briquettes in Haiti

	Maissade lignite	L'Azile coal (good)	High-volatile coal imports
Total costs, $/tonne	$77.60–86.00	$64.60–76.00	$77.60–82.20
Target selling price, $/tonne	$54.00[a]	$70.30[a]	$82.40[a]
Estimated profit (or loss), $/tonne	($23.60–32.00)[b]	($5.70)[b]–5.70	$0.20–4.60

[a]Assumed heat content of briquette:
Maissade: 3650 kJ/kg.
L'Azile: 4750 kJ/kg.
Imports: 5550 kJ/kg.
[b]Parentheses indicate negative values.

deforestation in one of the world's most eroded countries. The analysis indicated that charcoal from the pine plantation would be only marginally competitive in the cooking fuel market but that it would be an economically attractive alternative to coal as a fuel for cement production. Although this does not address the deforestation problem, the World Bank is currently negotiating an agreement with the government of Madagascar for a pilot pinewood carbonization project, since the biomass resource would otherwise be wasted. Among ORNL's contributions to the effort was an analysis of the acceptance in household markets of charcoal from pinewood. The analysis used a double-blind test of preferences for four types of charcoal and included both conventional survey and focus group instruments. The results indicated that pine charcoal (which tends to flame and produce more fly ash) was preferred by only about 20% of the respondents, but a mixture of pine charcoal and current market charcoal was preferred by about two-thirds of the respondents over either fuel type alone.

7.2.2 Decision Support System for AID's Office of Energy

S. B. Wright

A. E. Ekkebus
D. Justus*
M. Gorden†
C. S. Massingill
A. K. Roan‡
D. Smith†
T. J. Wilbanks

During FY 1986, the Energy Division completed the first phase of the development of a decision support system for AID's Office of Energy. The first part of the system was to be the creation of a responsive new technical information system for AID project managers, an activity which began in FY 1985. Influenced by the early success of this effort, the Office of Energy's FY 1986–88 Program Plan called for a second part of the system as well: an improved management decision support system, including a computer-based project control system.

Developing a decision support system for an organizational unit such as the Office of Energy is a special challenge. Compared with most of the agencies supported by the Division's Data Systems Research and Development (DSRD) Program (see Chaps. 5 and 6), the Office is very small in staff size and budget. Its day-to-day operation is complex—depending heavily on informal information flows, strongly affected by changing conditions and external needs, and linked in diverse ways to a great many external parties. Applying the normal tools of data systems design, from structured analysis to system architecture, to such an environment is possible in principle but generally infeasible in practice; the "investment costs" are simply not justified at that scale.

Instead, an approach was developed that included three related components, all built into the normal operations of the Office:

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*Ronson Management Corporation.
†Development Sciences, Inc.
‡Consultant.

1. An information resource center, to meet needs for both general energy-economic information and technology/issue-specific information. A flexible and responsive system was developed, combining limited hard-copy materials and microcomputer access to bibliographic and numerical data bases (both at a location in the proximity of the Office) with reference librarian support through ORNL's Central Research Library (via telephone or telecommunication). Tested and demonstrated in FY 1985, the resource center was placed into operation in FY 1986 and was successful in meeting Office needs. Moreover, it served to introduce many of the Office staff to state-of-the-art microcomputer, office automation, and telecommunication capabilities. At the end of FY 1986, the center was being transferred to space within the Office itself because of its proven value.
2. A rudimentary decision support system, related to a model of a longer-term "ideal" system, to meet needs for project management information. Based on a simple functional model of project initiation and management in the Office of Energy, together with a needs assessment, two prototype decision support tools were developed: (a) a microcomputer-based project control system, a menu-driven software package built around dBASE III designed to track project objectives, schedules, and expenditures and to meet Office needs for periodic reports (developed with the assistance of Development Sciences, Inc.); and (b) a prototype program information system, permitting access via a microcomputer to comprehensive information about AID project activities, past and present, in a particular program area such as renewable resources [developed with the assistance of Volunteers in Technical Assistance (VITA) and consultants]. Both are now in use by the Office of Energy.
3. A telecommunication capability to improve the capability of the Office to compile and exchange information with external parties about both issues and projects. In an organization that is so heavily oriented toward external interaction, the potential of modern telecommunications to add efficiency and effectiveness to Office activities is considerable. Even though realizing this potential is difficult in an agency in which microelectronic equipment procurements are slow and uncertain, the Office made significant progress during FY 1986 in telecommunications for text transmission, text compilation and editing, and interactive communications, using the resource center microcomputer and other Washington area equipment available to individual project managers. For example, a major draft report was compiled centrally, integrating materials keyboarded in California, Tennessee, Washington, D.C., and elsewhere—a first for the Office of Energy. Telecommunication links were established and demonstrated with a variety of national laboratories, contractors, and consultants.

7.2.3 Availability of Navy Mobility Fuels

G. R. Hadder S. Das
R. Lee R. M. Davis
T. A. Vineyard

Concerns about the reliability of military fuel supplies have increased in recent years because of changes in crude oil quality, shifts in refining capabilities, and other changes triggered by petroleum price instabilities. ORNL's Navy Mobility Fuels Forecasting System is a systematic methodology that has been used to analyze important issues of fuel availability and quality, considering implications for current and future military fuel using equipment.[6,7] During 1986, the system was used to analyze business-as-usual and four disruption scenarios in the year 1990:

1. Persian Gulf crude oil production capacity decreases by 11,000,000 bbl/d (1,750,000 m^3/d) for 90 d.
2. Persian Gulf crude oil production capacity decreases by 5,500,000 bbl/d (875,000 m^3/d) for one year.
3. Alaskan crude oil deliveries to destinations outside Alaska are lost for 90 d.
4. Mexican crude oil production capacity decreases for one year by the amount of business-as-usual Mexican crude oil exports.

Strategic Petroleum Reserves were not used in any scenario, nor were the provisions of the International Energy Agency sharing agreement initiated. The forecasting system first estimates the production of aggregate fuel product catagories, such as jet and distillate fuels, for key domestic and foreign refining regions. The aggregate estimates are developed with the Oil Market Simulation and the Petroleum Allocation Models. The aggregate fuel product category of jet fuel, for example, includes civilian jet fuel, Air Force JP-4 jet fuel, Navy JP-5 jet fuel, etc. A detailed Refinery Yield Model is then used to compute (1) the military jet fuel (JP-5) share of the estimated total jet fuel production, (2) the military marine diesel fuel (F-76) share of the estimated total distillate fuel production, and (3) the quality of all fuels.

The projected average daily production of jet fuel in the four disruption scenarios is displayed in Figs. 7.1 and 7.2. Among the scenarios considered, a decrease of 11,000,000 bbl/d (1,750,000 m^3/d) for 90 d in Persian Gulf crude oil production capacity (disruption 1) led to the greatest decline in jet fuel production in most of the regions. The impacts of the 5,500,000 bbl/d (815,000 m^3/d) Persian Gulf disruption were less pronounced. A disruption in the supply of Alaskan crude oil led to a major reduction in jet fuel production on the U.S. West Coast, but the shortfall was compensated by increased production on the U.S. Gulf Coast and to a lesser extent in several other regions. A disruption of Mexican crude oil supply had minimal effect on jet fuel production. All of the disruptions resulted in shifts in the mix of jet fuels that were produced.

The detailed Refinery Yield Model was used to analyze the availability of specific military fuels. The detailed analysis indicated that, compared with the estimated level of 1985 fuel requirements, the global supply of JP-5 should be adequate during the year-long Persian Gulf disruption. However, the supply of JP-5 could be insufficient for the shorter but more severe 90-d Persian Gulf disruption, the Alaskan disruption, and the Mexican disruption. The JP-5 production levels were statistically linked with the quantity of low-aromatics-content virgin blend stocks associated with the crude oil slates for the different scenarios. The Refinery Yield Model further showed that policies to combine a price increase and relaxation of specifications could result in JP-5 output levels sufficient to satisfy requirements well above the estimated 1985 level of usage.

In another study, the domestic versions of the Refinery Yield Model were enhanced with a capital equipment investment module. ORNL completed a study which predicts that U.S. Gulf and West Coast refinery investments for 1990–1995 could be used largely to support motor gasoline production. With the future domestic refinery configurations and anticipated operating constraints, it appears that the military will have to pay an increasingly large differential for JP-5 relative to the price of civilian jet fuel. The quality of domestically produced JP-5 is projected to be stable during the forecast period. F-76 was also studied and is expected to be in good supply, but its low-temperature fluidity will deteriorate.

ORNL-DWG 87C-12092

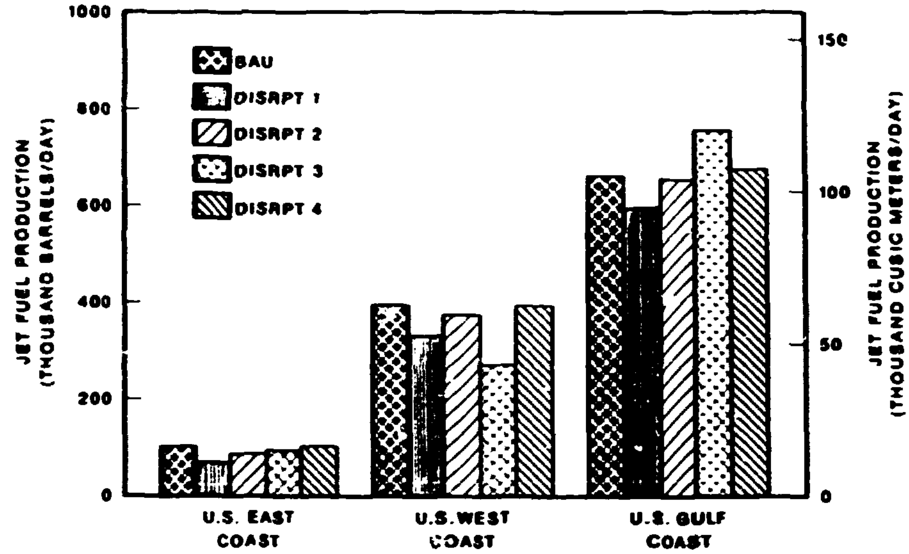

Fig. 7.1. Domestic jet fuel production for 1990 business-as-usual and disruption scenarios.

ORNL-DWG 87C-12093

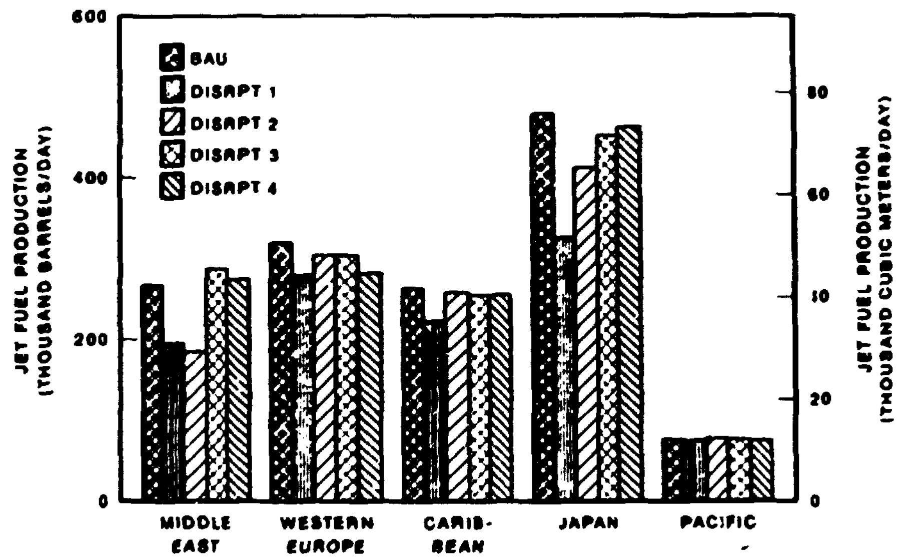

Fig. 7.2. Foreign jet fuel production of 1990 business-as-usual and disruption scenarios.

7.2.4 Environmental Effects of Chlorofluorocarbons

A. M. Perry

Concern over the possible environmental effects of continued releases of fully halogenated chlorofluorocarbons (CFCs) to the atmosphere has already led to restrictions on some uses of these compounds (e.g., their use as aerosol spray propellants in the United States). Additional restrictions are contemplated. In March 1985, in Vienna, 21 nations (including most of the major producers of CFCs) signed a Convention for the Protection of the Ozone Layer, which provided for the further adoption of protocols to the Convention which could embody international agreements for substantial further restrictions on the manufacture and use of CFCs. Such protocols are being negotiated.

In connection with our program for development of improved (more efficient) refrigeration and air-conditioning equipment and heat pumps, the Energy Division has been studying the CFC/ozone-reduction issue with particular emphasis on the question of the urgency for further CFC regulation and its impact on our development program.[8] A basic premise of this study is that large reductions in the earth's ozone shield (which could result from future CFC releases) should not and probably will not be allowed to occur but that small changes may be less harmful than the economic dislocations that would be necessary to prevent them. There is no clear basis yet for setting a practical limit on the decrease in ozone that might be accepted without alarm.

Nevertheless, Perry has suggested some highly tentative guidelines for use in exploring policies for future use of CFCs (i.e., that a 5% reduction in the ozone shield would probably be acceptable, a 10% reduction possibly so, a 20% reduction probably unacceptable, and a 30% reduction almost certainly unacceptable). Considerations underlying these suggestions include the following: (1) the response of ultraviolet (UV) intensity and biological effects to depletion of the ozone shield is highly nonlinear (i.e., doubling the depletion much more than doubles the effects); (2) both malignant melanomas and nonmelanoma skin cancers have increased far more in recent decades (for reasons other than ozone depletion) than would be expected to result from a 5–10% depletion of ozone, implying that small changes in total ozone thickness would have a minor effect compared with other changes already affecting the incidence of these diseases; (3) loss of yield or quality in crop plants and increases in mortality of aquatic organisms do not appear to be very severe for increases in UV intensity corresponding to 5-10% ozone depletion, and adaptation and adjustments, though not yet adequately evaluated, would be expected at least partly to offset these relatively small effects; (4) other projected atmospheric changes, such as an increase in methane concentration, may partly or entirely offset small reductions in ozone (e.g., induced by increasing atmospheric chlorine) but could not offset larger changes; (5) the greenhouse effect of CFCs that would produce a 5–10% reduction in total ozone is small compared with that expected to result from increasing atmospheric CO_2, but the larger ozone reductions (e.g., 20–30%) imply CFC concentrations that would produce a greenhouse effect comparable to that from doubling CO_2. Thus, a calculated 5–10% reduction in ozone before taking into account the potential compensation by changes in other atmospheric trace gases was tentatively adopted as the maximum allowable.

Various scenarios for future releases of CFCs were considered and were evaluated in terms of the maximum impacts (ozone depletion and contribution to the greenhouse effect) that would be associated with each scenario. Some scenarios were characterized by the initial rate of growth of annual CFC releases to the atmosphere, by the dates in the future when alternative technologies and practices (not contributing to the release of CFCs) could enter the market, and by the market penetration rates of the alternatives. Thus, each scenario for future CFC releases exhibits a period of sustained growth in emissions, followed by a period of decreasing growth rates, and a period of declining emissions, down to emission levels comparable to or less than the current ones. All of these scenarios involve more gradual changes than some that have been called for, such as a complete phaseout of CFC production over the next five to ten years.

A small sampling of these scenarios is shown in Fig. 7.3. The initial growth rate of annual emissions in this sample is 3%/year, which is consistent with projections from a number of studies by or for the United States Environmental Protection Agency. The date, t_o is the time when alternatives that do not release CFCs are assumed to attain a 1% market share. The market penetration parameter, b, is related to the time, T, required for the alternatives to increase their market share from 1% to 50% (i.e., $b = 4.59/T$). The values b = 0.12/year and 0.15/year correspond to T = 38 years and 31 years, respectively, to go from 1% to 50% of the market. We consider these to be conservative estimates of market penetration times for some major CFC markets, such as refrigeration and air conditioning. For other market segments, such as aerosol propellants, the market penetration times could obviously be much shorter.

The corresponding estimates of ozone depletion for these scenarios are shown in Fig. 7.4. Here, the ozone depletion is given relative to that for the case of continued CFC releases at current levels. Given present uncertainties in calculated ozone depletion and in what constitutes an "acceptable" level of ozone depletion, we judge that a relative ozone depletion of 1 or 2 may be considered

ORNL-DWG 86-13832

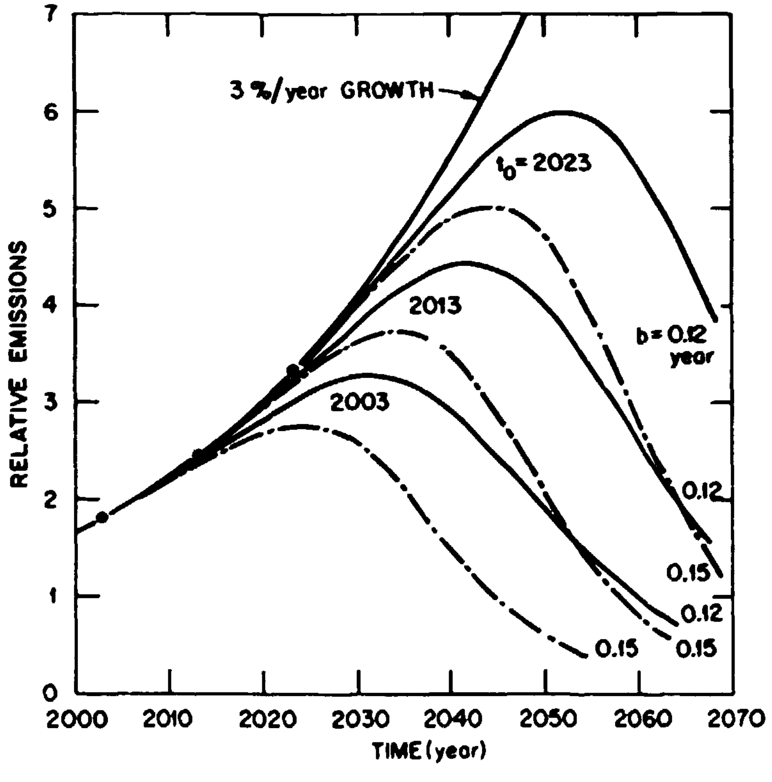

Fig. 7.3. CFC emission scenarios with remedial actions (market penetration scenarios).

ORNL-DWG 86-13831

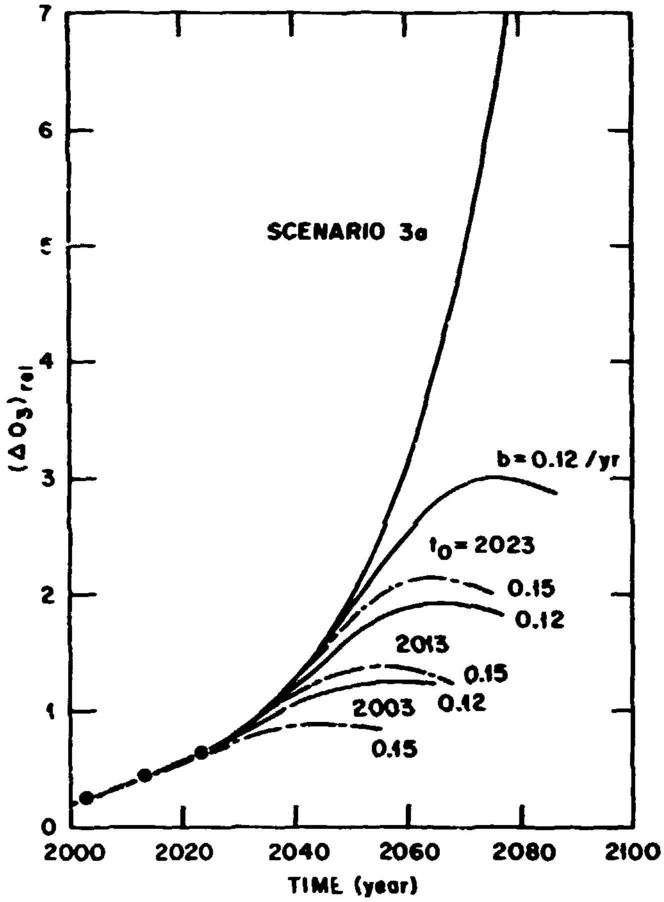

Fig. 7.4. Relative ozone depletion for certain market penetration scenarios with 3%/year initial growth in emissions. Also shown is a scenario with continued 3%/year growth rate of CFC emissions. The abscissa is the ozone depletion relative to that calculated for the case of constant CFC emissions at present rates.

acceptable. Thus, the three lowest scenarios in Fig. 7.4 are probably acceptable; the next two may prove to be acceptable, but the highest one is more likely not acceptable and should be avoided if possible.

For a much larger number of such scenarios, the maximum values of $(\Delta O_3)_{rel}$ (corresponding to the peaks of curves like those in Fig. 7.4) are displayed in Fig. 7.5.

The general conclusions from this study are as follows:

1. Very rapid reduction in CFC emissions (e.g., an 80% reduction over the next 5 to 10 years) is unnecessarily drastic.
2. Nevertheless, continued growth in CFC emissions at 3% per year or more, as seems quite likely in the absence of any further regulation, could not continue for many years without incurring a serious risk of unacceptably large impacts.
3. If demand for the services performed by CFCs continues to grow, alternatives will be needed within the next few decades; the required timing will depend on practically attainable rates of market penetration.
4. There appears to be time to sort out these issues better, but in the meantime it would be prudent to identify and prepare the needed alternatives.

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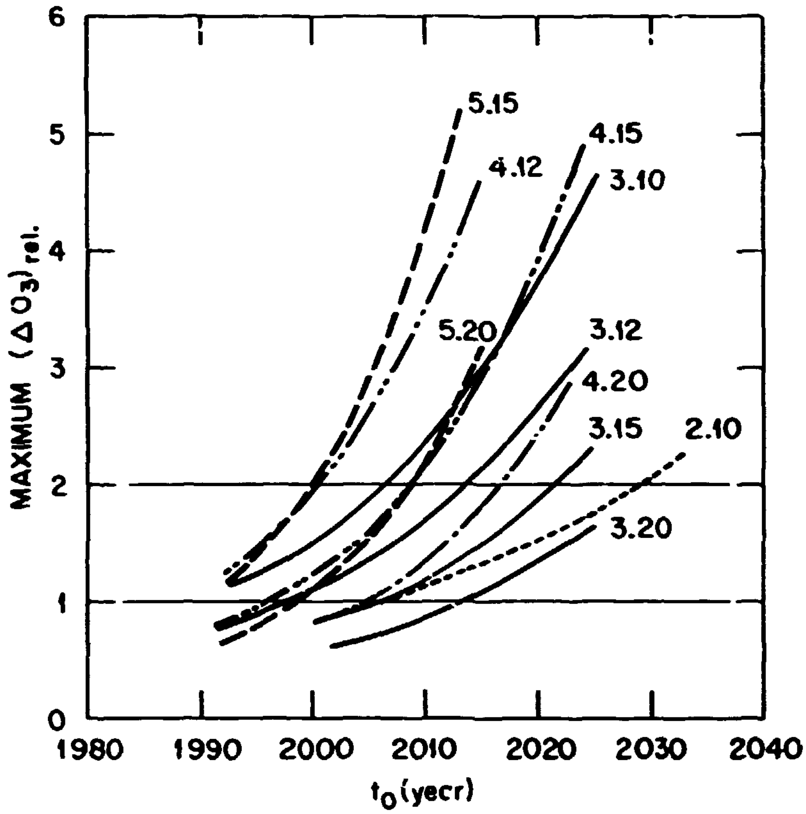

Fig. 7.5. Maximum relative ozone depletion for the market penetration scenarios vs the time when the market share of substitutes reaches 1%. Labels on the curves indicate initial growth rate before t_0 and the market penetration parameter b. For example, 3.15 means 3%/year initial growth rate and b = 0.15/year.

7.3 RESEARCH UTILIZATION

Most of the utilization of research conducted by the Integrated Programs part of the Division was done by sponsors. For instance, Energy Division perspectives on power system planning were featured at two international conferences on energy policy in Asia,[9,10] and the Division's coal briquetting work was presented at the First National Coal Conference in Pakistan.[11] Also notable were transfers of knowledge to the research community, such as lessons from several years of research on the economics of energy from wood in Liberia,[12] and transfers of information to the U.S. private sector, including a private firm interested in producing coal briquettes in Haiti.

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8. Publications, Presentations, and Professional Activities

8.1 ADVISORY COMMITTEE

The Advisory Committee for the Energy Division is appointed by Herman Postma, Director of Oak Ridge National Laboratory. The committee members for FY 1986 were as follows:

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8.2 PUBLICATIONS BY ENERGY DIVISION STAFF

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8.4 PRESENTATIONS BY ENERGY DIVISION STAFF

Arnold, H. G., "The Symbolic Processing Potential of Forth-Based Microcomputers," presented at the 1986 Rochester Forth Conference, University of Rochester, Rochester, N.Y., June 10–14, 1986.

Arrowood, L. F., "Applications of Artificial Intelligence to Military Domains," presented at the seminar entitled AI: The Emerging Technology, U.S. Air Force, Montgomery Ala., May 20–21, 1986.

Arrowood, L. F., "Artificial Intelligence Methodologies Applied to Critical Military Operations," presented to the Automated Systems Program Office, Gunter Air Force Stations, Montgomery, Ala., Apr. 22, 1986.

Barnes, P. R., "Nuclear Electromagnetic Pulse Research on Electric Power Systems," presented at the IEEE Winter Power Meeting, New York, Feb. 3–7, 1986.

Barnes, P. R., "On the Front-of-Wave of EMP Induced Power Line Surges," presented at the 1986 Nuclear EMP Meeting, University of New Mexico, Albuquerque, N.M., May 19–24, 1986.

Barnes, R. W., M. L. Emrich, and J. M. Hey, "Use of Productivity Tools in Department of Defense Automated Information Systems," presented at the Operations Research Society of America Annual Meeting, Los Angeles, Apr. 16, 1986.

Bjornstad, D. J., "A Comparative Analysis of Errors in Long-Term Econometric Forecasts," presented at the 25th Annual Meeting of the Southern Regional Science Association, New Orleans, Mar. 6–9, 1986.

Bownds, J. M., "A Formal Solution to a Classical Initial-Boundary Value Problem in Groundwater Hydraulics," presented to the Symposium on Differential Equations, Albuquerque, N.M., July 26–Aug. 1, 1986.

Brown, M. A., L. G. Berry, D. L. White, and P. Zeidler, "The Role of Auditor Salesmanship in Residential Conservation Incentive Programs: A Case Study," presented to the Great Pacific Gas and Electric Company, Oakland, Calif., Apr. 30–May 2, 1986.

Cantor, R. A., S. Rayner, and B. Braid, "The Role of Liability Preferences in Societal Technology Choices: Results of a Pilot Study," presented at the 1985 Annual Meetings of the Society for Risk Analysis, Washington, D.C., Oct. 8, 1985.

Cantor, R. A., "Examining the Myths of Nuclear Power Plant Construction Costs," presented to the Informal Discussion Group of Fundamental Issues in Science, Oak Ridge, Tenn., Apr. 17, 1986.

Cantor, R. A., "Nuclear Power Plant Construction Costs," presented at the Energy Division Information Meeting, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 19, 1986.

Chester, C. V., "Ballistic Missile Defense and Arms Control: The Role of Civil Defense," presented at the Conference on Ballistic Missile Defense and Arms Control, The Washington Institute, Washington, D.C., May 13, 1986.

Chester, C. V., "Nuclear War, Biomass Energy, and U.S. Agriculture," presented at the Sixth Annual Solar Biomass and Wind Energy Workshop, Atlanta, Feb. 25, 1986.

Chester, C. V., "Nuclear Winter," presented at the November 1985 meeting of the Oak Ridge Chapter of The Health Physics Society," Oak Ridge, Tenn., Nov. 21, 1985.

Chester, C. V., "Shelter Options," presented at The American Civil Defenses Association Annual Meeting, Los Angeles, Nov. 5, 1985.

Chin, S. M., and H. L. Hwang, "Dimensionality Reduction Procedures for K-Mean Cluster Analysis," presented at the ORSA/TIMS Meeting, Los Angeles, Apr. 14–16, 1986.

Christian, J. E., and D. Downing, "A Statistically Based Parametric Analysis of Exterior Envelope Thermal Mass Effect Predictions," presented at the ASHRAE/DOE/BTECC Conference on Thermal Performance of the Exterior Envelopes of Buildings III, Clearwater Beach, Fla., Dec. 2–5, 1985.

Courville, G. E., J. P. Sanders, and P. W. Childs, "Dynamic Thermal Performance of Insulated Metal Deck Roof Systems," presented at the ASHRAE/DOE/BTECC Conference on Thermal Performance of the Exterior Envelopes of Buildings III, Clearwater Beach, Fla, Dec. 2–5, 1985.

Creswick, F. A., "New and Future Heat Pump Technologies," presented at the Seminar on Meeting Customer Needs with Electric Heat Pumps, Kansas City, Kansas, sponsored by the American Public Power Association, Edison Electric Institute, Electric Power Research Institute, and the National Rural Electric Cooperative Association, Apr. 7–9, 1986.

Curlee, T. R., "Plastics Recycling: Economic and Institutional Issues," presented at the Technology Exchange Program: Plastics Recycling as a Future Business Opportunity, sponsored by the Plastics Institute of America, Washington, D.C., June 20, 1986.

Das, S., R. D. Perlack, and W. F. Barron, "BIOCUT: A Microcomputer Based Economic Evaluation Model for Wood Energy Plantations," presented at the TIMS/ORSA Joint National Meeting, Los Angeles, Apr. 14–16, 1986.

Das, S., and R. Lee, "Impact of Changes in Uranium Supply and Demand: An Application of the Domestic EUREKA Model," presented at the Second Symposium on Analytic Techniques for Energy, Natural Resources, and Environmental Planning, Philadelphia, Apr. 3–4, 1986.

Dinan, T. M., "Understanding the Market for Conservation Retrofit Technologies in the Commercial Sector," presented at the ACEEE 1986 Summer Study on Energy Efficiency in Building, Santa Cruz, Calif., Aug. 1986, and published in the proceedings.

Duncan, L. D., "Using DATATRIEVE as a COBOL Code Generator," presented at the Digital Equipment Computer Users Society Spring Symposium, Dallas, Apr. 27–May 2, 1986.

Emrich, M. L., "AI in Perspective," presented at AI for the DP Environment, Navy Regional Data Automation Center, Washington, D.C., Aug. 18, 1986.

Emrich, M. L., "An Introduction to Artificial Intelligence, presented to the U.S. Air Force, Montgomery, Ala., Mar. 27, 1986.

Emrich, M. L., "Expert Systems vs Decision Support Systems: A Comparative Analysis," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20–21, 1986.

Emrich, M. L., "Expert Systems: A Historical Perspective," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20–21, 1986.

Emrich, M. L., "Overview of AI/Expert Systems," presented to the U.S. Air Force, Montgomery, Ala., Nov. 6, 1985.

Emrich, M. L., "Research Areas That Must Be Addressed Before AI/C3 Systems Achieve Operational Success," presented at DSRD Seminar, Oak Ridge National Laboratory, Oak Ridge, Tenn., July 24, 1986.

Emrich, M. L., "The Knowledge Engineering Task," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20–21, 1986.

Fairchild, P. D., "Residential Heat Pump Applications," presented at the Seminar on Meeting Customer Needs with Electric Heat Pumps, Kansas City, Kansas, sponsored by American Public Power Association, Edison Electric Institute, Electric Power Research Institute, and the National Rural Electric Cooperative Association, Apr. 7–9, 1986.

Gant, K. S., M. V. Adler, and T. A. Rhea, "Federal Assistance in Radiological Emergencies: National Planning and Local Implementation," presented by T. A. Rhea at the 31st Annual Meeting of the Health Physics Society, Pittsburgh, June 29–July 3, 1986.

Gant, K. S., and R. E. Gant, "Careers in Applied Sciences: The Path Between Two Points Is Seldom a Straight Line," presented at Austin Peay State University Career Connections Week, Clarksville, Tenn., Feb. 18, 1986.

Greene, D. L., and P. S. Hu, "A Functional Form Analysis of the Short-Run Demand for Travel and Gasoline by One-Vehicle Households," presented at the Transportation Research Board 65th Annual Meeting, Washington, D.C., Jan. 13-16, 1986.

Griggs, E. I., and G. E. Courville, "Changes in Building Heating and Cooling Requirements Due to a Reduction in the Roof's Solar Absorptance," presented at the ASHRAE/DOE/BTECC Conference on Thermal Performance of the Exterior Envelopes of Buildings III, Clearwater Beach, Fla., Dec. 2-5, 1985.

Harrison, I. G., "Modeling the Highway Transportation of Spent Nuclear Fuel," presented at the Southeastern Association of American Geographers Meeting, Lexington, Ky., 1986.

Hilliard, M. R., "AI and C3: The State of the Art," presented to the U.S. Air Force, Montgomery, Ala., Feb. 18 and Mar. 27, 1986.

Hilliard, M. R., "The Future of AI: The Technology and the Dream," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20-21, 1986.

Hillsman, E. L., P. R. Coleman, and F. C. Kornegay, "A System to Estimate Population at Risk from Releases of Hazardous Materials," presented at the Annual Meeting of the Association of American Geographers, Minneapolis, May 4-7, 1986.

Hillsman, E. L., "Power System Planning in Developing Countries: Effects of Spatial and Institutional Structure on Uncertainty," presented at the International Association of Energy Economists Regional Conference on Energy Planning in South and Southeast Asia, Bangkok, Thailand, May 30-June 3, 1986.

Honea, R. B., "An Investigation of Landscape and Lake Acidification Relationships," presented at the Annual Meeting of Association of American Geographers, Minneapolis, May 4-7, 1986.

Honea, R. B., "Applied Geography: What Is It?" presented at East Tennessee State University, Johnson City, Tenn., Jan. 31, 1986.

Hu, P. S., "Athens Automation and Control Experiment: Data Validation Procedures," presented at the Athens Automation and Control Experiment Review Meeting, Oak Ridge, Tenn., May 1-2, 1986.

Hu, P. S., "Experiment Data and Data Management," presented at the Athens Automation and Control Experiment Public Review Meeting, Knoxville, Tenn., Dec. 2-6, 1985.

Hunsaker, D. B., Jr., "Worst-Case Accident Analysis in Environmental Assessments: A Follow-up Study," presented at Follow-up/Audit of Environmental Assessment Results, Banff, Alberta, Canada, Oct. 13-16, 1985.

Hwang, H. L., "Air Force AI Initiatives," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20-21, 1986.

Hwang, H. L., "Survey of AI/C3 Systems and Potential Applications to AFWIS Modernization Program," presented to the U.S. Air Force, Montgomery, Ala., Apr. 22, 1986.

Hwang, H. L., and A. S. Paulson, "Some Methods for the Multivariate Two-Sample Location Problem," presented at the Joint Statistical Meeting, Chicago, Aug. 18-21, 1986.

Jhirad, D., P. Sharafi, and E. L. Hillsman, "Innovative Approaches to Electric Power Delivery in Developing Countries," presented at the Asia/Near East Workshop on Energy Conservation and Private Power Generation, Bangkok, Thailand, Sept. 29-Oct. 3, 1986.

Jones, D. W., "Urbanization and Energy Use," presented in a session of the Energy Specialty Group at the Annual Meeting of the Association of American Geographers, Minneapolis, May 7, 1986.

Kerley, C. R., "Evaluation of the Net Economic Impact of Plant Closures: An Analysis of Three Uranium Enrichment Plants," presented at the 25th Annual Meeting of the Southern Regional Science Association, New Orleans, Mar. 6–9, 1986.

Kolb, J. O., and J. M. MacDonald, "Energy Conservation Opportunities in Commercial Buildings—Training and Services for Improved O&M," presented at the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Santa Cruz, Calif., Aug. 18–23, 1986.

Liepins, G. E., "A Brief Glimpse into Expert Systems; Their Applications (and Potential Applications) to Business and Manufacturing," presented to Oak Ridge Associated Universities, Oak Ridge, Tenn., Feb. 5, 1986.

Liepins, G. E., "Genetic Algorithms--Machine Learning and Adaptive Response," presented to the Education Foundation of the Data Processing Management Association, Washington, D.C., Sept. 22–23, 1986.

Liepins, G. E., "Lessons and Examples from a Prototype Detailer's Expert System," presented at the Federal Office Systems Exposition, Washington, D.C., Apr. 7–9, 1986.

Loffman, R. S., "A Survey of the Characteristics of Very High Level Languages," presented at the 1986 Rochester Forth Conference, University of Rochester, Rochester, N.Y., June 10–14, 1986.

Long, W., and P. A. Gnadt, "High Voltage Direct Current Research Program," presented at the CIGRE Meeting, Paris, Aug. 18–23, 1986.

MacDonald, J. M., "A Research Plan for Commercial Sector Retrofits," presented at the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Santa Cruz, Calif., Aug. 18–23, 1986.

MacDonald, J. M., "An Overview of Trends in Commercial Sector Energy Use in HVAC Controls," presented at TVA Energy: An Integrated Approach, Chattanooga, Tenn., May 1986.

McCold, L. N., J. A. Schlegel, and D. C. Hewitt, "Technical and Practical Problems of Developing and Implementing an Improved Retrofit Audit," presented at the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Santa Cruz, Calif., Aug. 18–23, 1986.

McConnell, B. W., P. F. Hettwer, and L. M. Burrage, "Impact of Steep Front, Short Duration Impulses on Power Systems Apparatus and Insulation: A Critical Review," presented at the 1986 International Symposium on Electrical Insulation, Washington, D.C., June 8–11, 1986.

McConnell, B. W., and L. M. Burrage, "Assess the Impact of Steep Front, Short Duration Impulses on Power System Insulation—A Review of Progress to Date," presented at the 1986 Nuclear EMP Meeting, University of New Mexico, Albuquerque, N.M., May 19–24, 1986.

McGill, R. N., "Methanol Fleet Activities Progress Report," presented at the DOD/DOE Coordination Meeting on Federal Methanol Vehicle Fleets, Washington, D.C., February 1986.

McGill, R. N., "The Federal Methanol Fleet Demonstration Project," presented at the Transportation Research Board committee meeting, Washington, D.C., January 1986.

McGill, R. N., "The Federal Methanol Fleet—A Progress Report," presented at the 1985 Washington Conference on Alcohol, Washington, D.C., November 1985.

McKinley, K. F., "Economics of Distribution Automation," presented at the Eighteenth Southeastern Symposium on System Theory, University of Tennessee, Knoxville, Tenn., Apr. 7–8, 1986.

Mileti, D., and J. Sorensen, "Determinants of Organizational Effectiveness in Crisis," presented at the First International Conference on Industrial Crisis Management, New York, Sept. 6, 1986.

Morell, J. A., "Evaluating a Federal Effort to Spur Invention and Innovation: The U.S. Department of Energy's Energy Related Inventions Program," presented to the Business School of the University of Pittsburgh, May 29, 1986.

Morell, J. A., "Evaluation of Innovation Promotion Programs: The Example of the Energy Related Inventions Program," presented at the Ninth Annual Meeting of the Eastern Evaluation Research Society, Rutgers University, New Brunswick, N.J., May 19, 1986.

Morell, J. A., "Understanding Managers' Use of Office Automation," presented at the School of Urban and Public Planning, Carnegie-Mellon University, Pittsburgh, May 26, 1986.

Neal, D. M., "A Cross-Societal Comparison of Swedish and United States Emergency Time Emergent Group Behavior," presented at the American Sociological Association's Annual Meetings, New York, September 1986.

Neal, D. M., "Further Refinements Toward Studying Emergent Groups in Disaster Situations," presented at the Eastern Sociological Society's Annual Meetings, New York, April 1986.

Peele, E., "Hazardous Waste: Are There Ways Out of the NIMBY Impasse?," presented at the Tenth Annual Minnesota Solid Waste Conference, Minneapolis, Feb. 18, 1986.

Peelle, E., "Innovative Process: The MRS Task Force," presented at the Rene Dubos Environmental Management Institute Annual Symposium on Land Use, New York, April 3, 1986.

Petrich, C. H., and M. M. Swihart, "Technical Findings: Aesthetic Impacts of Hydroelectric Projects in the Owens River Basin," presented to Public, State, and Federal Agencies at the Federal Energy Regulatory Commission, Bishop, Calif., Dec. 3–5, 1985.

Purucker, S. L., "Athens Project Review," presented at the Athens Automation and Control Experiment Project Review Meeting, Knoxville, Tenn., Dec. 3–5, 1985.

Purucker, S. L., "Athens Project Review," presented to the Athens Automation and Control Experiment Advisory Group Meeting, Oak Ridge, Tenn., May 1–2, 1986.

Purucker, S. L., "Baltimore Gas and Electric Company Application of Athens Experimental Data in a Planning Study," presented to Baltimore Gas and Electric Company, Baltimore, May 13, 1986.

Purucker, S. L., "The Athens Automation and Control Experiment Distribution Automation Project," presented at the 1986 Rural Electric Power Conference, Charleston, S.C., Apr. 21, 1986.

Purucker, S. L., "The Athens Experiment and Results to Date," presented to the Kansas Electric Research Group and Tennessee Valley Electric Power Producer's Association, Athens, Tenn., May 20, 1986.

Rayner, S., "Applied Anthropology of Industrial Society," presented at the University of Pennsylvania, Philadelphia, Oct. 3, 1985.

Rayner, S., "How Fair is Safe Enough? The Cultural Approach to Societal Technology Choice," presented at the International Colloquium, Evaluer et Maitriser Les Risques: La Societe Face Au Risque Majeur, Centre National De Recherche Scientifique, Chantilly, France, Jan. 29, 1986.

Rayner, S., "Not in My Backyard: The Politics of Hazardous Waste Disposal," presented at Old Dominion University, Norfolk, Va., Nov. 5, 1985.

Rayner, S., "Redefining Risk," keynote address to the Annual Research Conference, University of Minnesota Department of Anthropology, Lake Itasca, Minn., May 9, 1986.

Rayner, S., "Rules That Keep Us Equal: The Far Left in Britain and Anti-Nuclear Groups in the USA," presented at the American Anthropological Association Annual Meeting, Washington, D.C., 1985.

Rayner, S., "Secular Sectarians: Millenarianism and the British Far Left," presented at Princeton University, Princeton, N.J., Mar. 11, 1986.

Rayner, S., "Social Impact Assessment and Technology Choice," presented at the American Sociological Association Annual Meeting, New York, Sept. 8, 1986.

Rayner, S., "The Use and Abuse of Ignorance in Science for Policy," presented at Oak Ridge Associated Universities, Oak Ridge, Tenn., Nov. 14, 1985.

Reed, J. H., G. R. Wetherington, and W. R. Nelson, "The Impact of Load Control on a Distribution System," presented at the IEEE/Power Engineering Society Transmission and Distribution Conference and Exposition, Anaheim, Calif., Sept. 17, 1986.

Rizy, D. T., E. W. Gunther, and F. McGranaghan, "Transient and Harmonic Voltages Associated with Capacitor Switching on Distribution Systems," presented at the IEEE/PES 1986 Transmission and Distribution Conference, Anaheim, Calif., Sept. 14–19, 1986.

Rizy, D. T., "Implementation of Real-Time Regulator and Capacitor Control on the Athens Utilities Board," presented at Southeastcon '86 IEEE Region 3 Conference and Exhibit, Richmond, Va., Mar. 23–26, 1986.

Schlegel, J. A., D. C. Hewitt, L. A. O'Leary, and L. N. McCold, "Improving Infiltration Control Techniques in Low-Income Weatherization," presented at the ACEEE 1986 Summer Study on Energy Efficiency in Buildings, Santa Cruz, Calif., Aug. 18–23, 1986.

Shelton, R. B., "The Application of Smokeless Briquettes in Developing Countries: The Case of Haiti and Pakistan," presented at The First Pakistan National Coal Conference, Coal Development Potential in Pakistan, Karachi, Pakistan, Feb. 22–26, 1986.

Snyder, C. E., "Advanced Distributed Processing with FOCUS and PC/FOCUS," presented at FUSE '86 (International FOCUS Users Group) Meeting, New Orleans, Apr. 7–12, 1986.

Snyder, C. E., "Data Quality: A Strategic Perspective," presented at the American Society for Information Science 49th Annual Meeting, Chicago, Sept. 28–Oct. 2, 1986.

Sorensen, J., "Emergency Response to Oil and Gas Facility Disruption," presented at the Applied Geography Conference, Denton, Tex., November 1985.

Sorensen, J., "Evacuation Planning for Nuclear Power Plants," presented at the American Nuclear Society Topical Meeting on Radiological Emergencies, Bethesda, Md., Sept. 17, 1986.

Sorensen, J., "Warning Systems in the 1985 Cheyenne Flash Flood," presented at the Big Thompson Symposium, Boulder, Colo., July 18, 1986.

Southworth, F., "A Dynamic Urban Spatial Structure Model Incorporating Multi-purpose Travel Chains," presented at the North American Regional Science Association Meetings, Philadelphia, November 1985.

Southworth, F., "On the Transfer of Ridesharing Technology," presented at the Association of American Geographers Annual Meetings, Minneapolis–St. Paul, May 1986.

Stevens, R. A., "Performance of Conventional Power Flow Routines for Real-Time Distribution Automation Applications," presented at the Eighteenth Southeastern Symposium on System Theory, University of Tennessee, Knoxville, Tenn., Apr. 7–8, 1986.

Stovall, J. P., "Implementation of a Distribution Automation System—The Automation and Control Experiment," presented at the Insights '86 Conference, Washington, D.C., Sept. 8–9, 1986.

Taylor, E. R., Jr., J. C. Crouse, and P. R. Barnes, "EMP Experimental Tests on Large Electric Power Apparatus," presented at the 1986 Nuclear EMP Meeting, University of New Mexico, Albuquerque, N.M., May 19–24, 1986.

Tonn, B. E., D. Kunz, D. Barnes, and G. Hosack, "A Microcomputer Based Expert System Prototype," presented at the Joint National ORSA/TIMS Meeting, Atlanta, November 1986.

Tonn, B. E., "The How and Why of Prototyping Expert Systems," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20–21, 1986.

Tonn, B. E., "Uncertainty in Artificial Intelligence and Expert Systems," presented at the seminar entitled AI: The Emerging Technology, sponsored by the U.S. Air Force, Montgomery, Ala., May 20–21, 1986.

Truett, L. M., "Evaluation Report: Implementation of the Source Data System," presented at PSA, Washington, D.C., Oct. 16, 1985.

Van Dyke, J. W., and P. S. Hu, "Factors of Variances in Calculating a Discount Rate for Project Analysis," presented at the 1986 Annual Statistical Meetings of American Statistical Association, Chicago, Aug. 18–21, 1986.

Vogt, B., and J. Sorensen, "Convergence Behavior and Risk Perception at Mt. St. Helens," presented at the American Sociological Association Annual Meeting, New York, Sept. 2, 1986.

Vogt, D. P., "Regional Economic Impact Assessment System," presented at the Energy Division Information Meeting, Oak Ridge National Laboratory, Oak Ridge, Tenn., Aug. 19, 1986.

Vogt, D. P., "Regional Economic Modeling," presented as guest lecturer to the University of Tennessee Graduate School of Planning, University of Tennessee, Knoxville, Tenn., May 5, 1986.

Wilbanks, T. J., "Approaches to Energy Planning," presented at the Conference on Energy Policy for the Americas, San Juan, Puerto Rico, October 1985.

Wilbanks, T. J., "National Energy Planning for Developing Countries," presented at the Association of American Geographers Meeting, Minneapolis, April 1986.

Wilbanks, T. J., "Predicting Energy and Technological Crises in the Sunbelt," presented at conference entitled The Sunbelt: A Region and Regionalism in the Making?, Miami, November 1985.

Yount, S. L., "High Tech's Role in Personnel Management," presented at the Executive Seminar Center, Oak Ridge, Tenn., Aug. 12, 1986.

Yount, S. L., and N. B. Gove, "An Information Retrieval System for Chemical Separations Scientists," presented at the American Chemical Society Annual Meeting, New York, Apr. 13–18, 1986.

8.5 PROFESSIONAL ACTIVITIES AND AWARDS

Bownds, J. M., Referee, Society of Industrial and Applied Mathematics, *Journal of Mathematical Analysis.*

Bownds, J. M., Referee, Society of Industrial and Applied Mathematics, *Journal on Numerical Analysis.*

Bownds, J. M., Reviewer, American Mathematical Society, *Mathematical Reviews.*

Brown, M. A., Committee Member, Long-Range Planning Committee of the Urban Geography Specialty Group, Association of American Geographers.

Brown, M. A., Editorial Board, *Annals of the Association of American Geographers*.

Brown, M. A., Member, National Science Foundation Review Panel, Geography and Regional Science Division.

Brown, M. A., Member, Publications Committee, Association of American Geographers.

Brown, M. A., Reviewer, *Urban Geography, Environment and Planning, A Political Geography Quarterly, Annals of the Association of American Geographers*, The Rockefeller Foundation and the National Science Foundation.

Carnes, S. A., Reviewer, *Risk Analysis: An International Journal*.

Chester, C. V., Technical Program Chairman, American Nuclear Society Topical Meeting on Radiological Accidents: Perspectives and Emergency Planning, Bethesda, Md., Sept. 15–17, 1986.

Creswick, F. A., Chairman, ASHRAE TC 7.6, Unitary Air Conditioners and Heat Pumps.

Dale, S. J., Chairman, IEEE Electrical Society Gaseous Dielectrics Committee.

Dale, S. J., Invited Technical Member, U.S. National CIGRE Committee 15 on Insulation.

Dale, S. J., Invited Technical Member, U.S. National CIGRE Committee 21 on Power Cables.

Dale, S. J., Recipient, IEEE Congressional Fellows Award, May 1986.

Das, S., Session Chairman, Microcomputer Applications, TIMS/ORSA Joint National Meeting, Los Angeles, Apr. 14–16, 1986.

Fulkerson, W., Elected, Fellow of the American Association for the Advancement of Science, May 29, 1986.

Fulkerson, W., Recipient, Martin Marietta Energy Systems, Inc., 1986 Award for Operational Performance.

Gant, K. S., Publications Chairman, American Nuclear Society Topical Meeting on Radiological Accidents: Perspectives and Emergency Planning, Bethesda, Md., Sept. 15–17, 1986.

Greene, D. L., Chairman, Transportation Research Board, National Research Council, Committee on Energy Conservation and Transportation Demand, A1F01, 1983–1986, 1986–1989.

Greene, D. L., Member, Committee on Transportation Information Systems and Data Requirements, 1983–1986, 1986–1989.

Greene, D. L., Recipient, ORNL Special Recognition Award, Oak Ridge National Laboratory, 1986.

Hilliard, M. R., Council Member, Operations Research Society of America, Special Interest Group in Artificial Intelligence.

Hilliard, M. R., Referee for International Symposium on Methodologies for Intelligent Systems, *American Journal of Mathematical and Management Sciences, SIAM Journal on Algebraic and Discrete Methods*.

Hillsman, E. L., Citation Award, 1986 Applied Geography Project Award.

Hirst, E., Associate Editor, *Energy*.

Hirst, E., Editorial Board, *Energy Policy*.

Hirst, E., Editorial Board, *Energy Systems and Policy*.

Hirst, E., Editorial Board, *Evaluation and Program Planning.*

Hirst, E., Editorial Board, *Journal of Environmental Systems.*

Hirst, E., Editorial Board, *The Energy Journal.*

Hirst, E., Member, Committee on Behavioral and Social Aspects of Energy Consumption and Productions, National Academy of Sciences/National Research Council.

Hirst, E., Member, Research Advisory Council, Niagara Mohawk Power Corp. Conservation Programs.

Hirst, E., Senior Fellow, American Council for an Energy-Efficient Economy.

Hunsaker, D. B., Jr., Board of Directors, National Association of Environmental Professionals, Washington, D.C. (appointed August 1986).

Hunsaker, D. B., Jr., Technical Reviewer and Review Coordinator, *Journal of the Air Pollution Control Association*, Pittsburgh, Pennsylvania.

Hunsaker, D. B., Jr., Technical Reviewer, The Environmental Professional, *Journal of the National Association of Environmental Professionals*, Washington, D.C.

Hwang, H. L., Referee for International Symposium on Methodologies for Intelligent Systems, *American Journal of Mathematical and Management Sciences, SIAM Journal on Algebraic and Discrete Methods.*

Kolb, J. O., Recipient, Martin Marietta Energy Systems, Inc., 1986 Award for Community Service.

Kornegay, F. C., Recipient, Martin Marietta Energy Systems, Inc., 1986 Award for Technical Achievement.

Liepins, G. E., Evaluated as Best Speaker in Session, Federal Office Systems Exposition, Apr. 7–9, 1986.

Liepins, G. E., Board Member, ORSA/TIMS AI Special Interest Group.

Liepins, G. E., Certified Data Processor.

Liepins, G. E., Newsletter Editor, ORSA/TIMS AI Special Interest Group.

Liepins, G. E., Session Chairman, Artificial Intelligence Applications, ORSA/TIMS National Meeting, Apr. 14–16, 1986.

Liepins, G. E., Vice President for Education EATE American Production and Inventory Control Society.

McGill, R. N., Assistant Chairman, Technical Session, SAE Annual Congress, February 1986.

McGill, R. N., Co-chairman, Gaseous Fuels Session, Automotive Technology Contractors' Coordination Meeting, October 1985.

Morell, J. A., Leader, Topical Interest Group on Information Technology, American Evaluation Association.

Neal, M., Session Organizer and Discussant, Collective Behavior and Social Movements Section, North Central Sociological Association's Annual Meeting, Cincinatti, April 1986.

Peelle, E. B., Elected, Fellow of the American Association for the Advancement of Science, May 29, 1986.

Perez-Blanco, H., Chairman, ASHRAE TC 8.3, Absorption and Heat Operated Machines.

Perez-Blanco, H., Recipient, Martin Marietta Energy Systems, Inc., 1986 Award for Inventor.

Perez-Blanco, H., Technical Communication Award in Recognition of Achievement in Technical Reports, *Comparative First- and Second-Law Analysis of an Absorption Cycle.*

Petrich, C. H., Award of Distinction in Technical Reports from the Society for Technical Communication, East Tennessee Chapter, 1986, for "Site Development Planning for Energy Management," by R. L. Wendt, C. H. Petrich, and A. H. Voelker.

Purucker, S. L., Chaired "Distribution Automation" session at The Eighteenth Southeastern Symposium on System Theory, Knoxville, Tenn., Apr. 7, 1986.

Purucker, S. L., Member IEEE Distribution System Design Working Group.

Purucker, S. L., Member IEEE Load Control Working Group.

Purucker, S. L., Member, EPRI Advisory Board on Project RP-2592, "Distribution Automation and Load Control System."

Rayner, S., Adjunct Assistant Professor of Sociology, University of Tennessee.

Rayner, S., Manuscript Referee, *Risk Analysis: An International Journal.*

Rayner, S., Reviewer, National Science Foundation, Anthropology Program.

Rayner, S., Reviewer, National Science Foundation, Small Business Program.

Rayner, S., Senior Research Associate, Centre for Occupational and Community Research, United Kingdom.

Ricci, E., Member, Executive Committee, Isotopes and Radiation Division, American Nuclear Society, 1986–1989.

Ricci, E., Member, National Board of Directors, American Nuclear Society, 1983–1987.

Ricci, E., Member, National Executive Committee, American Nuclear Society, 1986–1987.

Roop, R. D., Member, Ecology Committee, Water Pollution Control Federation.

Rush, R. M., Member, Admittance Committee of Oak Ridge Chapter, Sigma Xi.

Sadlowe, A. R., Vice Chairman, American Society of Mechanical Engineers, Technology & Society Division.

Sexton, F. L., Chairman, East Tennessee–Oak Ridge IEEE Computer Society Chapter.

Snyder, C. E., Martin Marietta Energy Systems, Inc., Small Business Advocate Award, FY 1986.

Sorensen, J. H., Laboratory Fellow, Hazard Assessment Laboratory, Colorado State University, Ft. Collins, Colo.

Sorensen, J. H., Member, International Research Group on Risk Communications.

Sorensen, J. H., Member, National Academy of Science, Committee on Natural Disaster, Cheyenne Flood Post Disaster Study Team.

Sorensen, J. H., Member, Technical Program Committee, American Nuclear Society, Topical Meeting on Radiological Accidents, 1986.

Sorensen, J. H., Organizer and Chair, Session on Energy Research, "Eighth Applied Geography Conference, November 1985.

Wilbanks, T. J., Advisory Editor, Syracuse Geographical Series.

Wilbanks, T. J., Association Representative to Section K (Social, Economic, and Political Sciences) of the American Association for the Advancement of Science, Association of American Geographers.

Wilbanks, T. J., Chair, Honors Committee, Association of American Geographers, 1987.

Wilbanks, T. J., Councilor, American Geographical Society.

Wilbanks, T. J., External Evaluator, Energy, Environment, and Resources Center, University of Tennessee, July 1986.

Wilbanks, T. J., Honors, Association of American Geographers.

Wilbanks, T. J., Manuscript Referee, *Science; Annals, AAG; The Professional Geographer;* and *Social Science Quarterly*.

Wilbanks, T. J., Member, International Consultative Group, Energy Research Program, Universidad de Chile.

Wilbanks, T. J., Member, Advisory Committee, *ESPER Journal*.

Wilbanks, T. J.. Member, Working Group on Energy, International Geographical Union.

Wilbanks, T. J., Proposal Evaluator, Committee for Research and Exploration, National Geographic Society.

Wilbanks, T. J., Proposal Evaluator, Human Geography and Regional Science Program, National Science Foundation.

Wilbanks, T. J., Treasurer and Member of the Board of Directors, 27th International Geographical Congress, 1992.

Witten, A. J., Recipient, Martin Marietta Energy Systems, Inc., 1986 Award for Technical Achievement.

8.6 WORKSHOPS AND SYMPOSIA ORGANIZED BY ENERGY DIVISION STAFF

AI for the DP Environment, Navy Regional Data Automation Center, Washington Navy Yard, Washington, D.C., Aug. 18, 1986, organized by M. L. Emrich.

AI: The Emerging Technology, Gunter Air Force Station for the U.S. Air Force, Montgomery, Ala., May 20–21, 1986, organized by M. L. Emrich.

American Nuclear Society Topical Meeting on Radiological Accidents: Perspectives and Emergency Planning, Sept. 15–17, 1986, Assisted in organizing by C. V. Chester, K. S. Gant, and M. V. Adler.

Athens Automation and Control Experiment Project Review Meeting, Knoxville, Tennessee, Dec. 3–5, 1985, organized by AACE Project Team.

Athens Automation and Control Experiment Utility Advisory Group Meeting, Athens, Tennessee, Oct. 2–3, 1986, organized by J. P. Stovall and D. T. Rizy.

National Workshop: Field Data Acquisition for Building and Equipment Energy-Use Monitoring, Dallas, Oct. 15–18, 1985, organized by G. E. Courville and P. D. Fairchild.

Rules, Decisions, and Inequality in Egalitarian Social Groups, Paper Session, 1985 Annual Meeting American Anthropological Association, Washington, D.C., Nov. 3, 1985, organized by J. F. Flanagan and S. Rayner.

Session on Energy Research, Eighth Applied Geography Conference, November 1985, organized by J. Sorensen.

The First Pakistan National Coal Conference, Karachi, Pakistan, Feb. 22–26, 1986, organized by T. J. Wilbanks.

1986 IEEE International Symposium on Electrical Insulation, Washington, D.C., June 8–11, 1986, organized by S. J. Dale, General Chairman.

8.7 ENERGY DIVISION CONSULTANTS AND SUBCONTRACTORS

8.7.1 Consultants

P. R. Achenbach
F. Arumi-Noe
H. W. Askins
M. H. Barnes
J. V. Beck
W. J. Biermann
J. W. Blaylock
R. A. Brechbill
H. W. Bushing
T. L. Cox
M. Dennis
B. H. Deverick
C. C. Diemond
W. P. Ellis
D. Epple
P. L. Fisher
C. Fowlkes
D. D. Francis
A. A. Frank
H. Frank
W. Friggle
D. Gately
L. P. Gerlach
D. Goldberg
D. Goldenberg
J. J. Grainger
E. I. Griggs
L. L. Grigsby
G. Grossman
D. T. Harrje
C. M. Ho
T. B. Jabine
D. E. Kash
F. Kertesz
D. W. Kiefer
C. Komanoff
G. E. Lake
P. E. Lambert
A. J. Laub
E. E. Leamer
M. Lessen
R. K. Lester
D. B. Levine
R. Lichtman
C. Longmire
T. W. Mason
J. McCorkle
J. M. McIntyre
L. A. McNeely
J. R. Mercier
R. E. Minturn
J. E. Molyneux
C. Moody
A. B. Newton
R. L. Parker
J. B. Patton
A. H. Pelofsky
R. W. Peplies
H. M. Pflanz
F. J. Powell
B. R. Ragins
J. J. Ray
A. R. Roan
R. C. Robertson
G. F. Roberts
C. Sieben
W. L. Smalley
R. M. C. So
R. W. Stafford
W. F. Stoecker
R. L. Sullivan
R. A. Timbert
R. H. Turner
E. F. Vance
R. C. Waag
S. P. Walldorf
D. Wasserman
J. M. Weingart
D. L. White
R. D. White
C. C. Wilson
A. S. Wineman
T. S. Wood
D. R. Younger

8.7.2 Subcontractors by Company

Adams Craft Herz Walker
Advanced Systems Technology Corporation
AER Enterprises
Aercon, Inc.
Aeronautical Research Associates
AFTAB Associates, LTD
Allen & Hoshall, Inc.
American Consulting Engineers Council
American Institute of Architects
American Management Systems, Inc.
Analysas Corporation
Analytic Disciplines, Inc.
Anderson-Major Planning Consultants
Applied Management Sciences, Inc.
Applied Sciences Group, Inc.
Argonne National Laboratory
Arthur D. Little, Inc.
Association of Collegiate Schools
Athens Utility Board
Auburn University
Automated Sciences Group
Automation Associates, Inc.
Automation Management Consultants
AV Consultants
A&T Systems, Inc.
A. F. Meyer & Associates, Inc.
Baltimore Gas & Electric Company
Battelle Columbus Laboratories
Biomass Energy Foundation, Inc.
Boston College, Office of Research
Brookhaven National Laboratory
Camden Corporation
Carnegie Mellon University
Carrier Corporation
Centaur Associates, Inc.
Chamberlain Manufacturing Corporation
Clemson University
Collieries Management Corporation
Colorado Nuclear Corporation
Colorado State University
Columbia Technologies
Commuter Transportation
Computer Aided Planning
Computer Data Systems, Inc.
Computer Sciences Corporation
Consad Research Corporation
Consumer Energy Council of America
Control Data Corporation
CRC Systems, Inc.
Cristy Consultants, Inc.
De Lucia & Associates, Inc.
Delta Electronics Control Corporation
Desert Research Institute
Development Sciences, Inc.
Digital Equipment Corporation
Doty Associates, Inc.
East-West Center
Economic System Analysis, Inc.
Ecotope, Inc.
Edwards & Associates
Electric Research & Management, Inc.
Electrotek Concepts, Inc.
Energy Concepts
Energy & Environmental Analysis, Inc.
Ener-Serv, Inc.
Ensys Energy & Systems, Inc.
Environmental Protection Agency
Environmental Systems Management, Inc.
ESG Associates, Inc.
Evaluation Research Corporation
Flood Loss Reduction Associates
Foster-Miller Associates, Inc.
Franklin Institute
Gamma Engineering Corporation
Genasys Corporation
General Electric Company
George Washington University
Georgia Institute of Technology
Golder & Associates
Grant-Thornton
Grumman Data Systems Corporation
H & R Technical Associates, Inc.
Hadron, Inc.
Hagler, Bailly & Company
Harvard University
Honeywell, Inc.
Idea, Inc.
Information Systems Technologies, Inc.
Institute of Gas Technology
Integrated Systems, Inc.
Interaction Associates, Inc.
International Energy Associates, LTD
INTRAG, Inc.
JDS Group, Inc.
John Kososki & Associates
Knoxville College
L. D. Ridgeway, Inc.
Lawrence Berkeley Laboratory
Los Alamos National Laboratory
Lutech, Inc.
Management Analysis Corporation
Mantech International Corporation
Martin Marietta Corporation
Massachusetts Institute of Technology

Maxima Corporation
Maxwell Laboratories, Inc.
McGraw-Edison Corporation
McGraw-Edison Power Systems Group
MCI/Consulting Engineers, Inc.
Mechanical Technology, Inc.
Michigan State University
Minnegasco
Mitre Corporation
Mohawk Research Corporation
NASA Lewis Research Center
National Bureau of Standards
Network Strategies, Inc.
New Jersey Institute of Technology
Niagara Mohawk Power Corporation
North American Heating & Cooling
North Carolina State University
Northeast Midwest Institute
Northwestern University
Nuclear Assurance Corporation
Oak Ridge Associated Universities
Old Dominion University
Oracle Corporation
ORI, Inc.
P. E. Lamoreaux and Associates
PEI Associates, Inc.
Perceptronics, Inc.
Phillips Engineering Corporation
Planning Analysis Corporation
Portland Cement Association
Power Technologies, Inc.
Presearch, Inc.
Professional Analysis, Inc.
Purdue Research Foundation
Pyros, Inc.
R. W. Graf Construction Company
Regional Economic Models, Inc.
Rensselaer Polytechnic Institute
Resource Consultants, Inc.
Resource Management Associates
Resources Dynamics Corporation
Resources Emphasis, Inc.
Resources for the Future
ROH, Inc.
Rolands & Associates Corporation
Ronson Management Corporation
SPS, LTD
SRD Tomco Systems, Inc.
SRI International
Sage Federal Systems, Inc.
Samprit Chatterjee, New York
Sandia Laboratories
Sanford Cohen & Associates
Science Applications International
Science & Technology, Inc.
Scientific Service, Inc.
Scott, Wilson, Kirkpatrick & Partners
Ships Missile Systems Consultants
Software Solutions, Inc.
Solar Energy Research Institute
Southern Electric International
Sperry Corporation
Sterling Hobe Corporation
Stevens Institute of Technology
Synergic Resources Corporation
Syscon Corporation
Systematic Research, Inc.
Systems/Software, Inc.
T. J. Murphy & Associates
Technology Management Corporation
Techplan Corporation
Tectonics Research, Inc.
Tennessee Technological University
Tennessee Valley Authority
Texas Instruments, Inc.
The Davis Group, Inc.
Tidewater Consultants, Inc.
Trane Company
University of Akron
University of California
University of California at Los Angeles
University of Connecticut
University of Florida
University of Illinois
University of Kentucky
University of Minnesota
University of Oregon
University of Rochester
University of South Carolina
University of South Florida
University of Southern California
University of Tennessee
University of Texas
University of Wisconsin
URS Company
U.S. Department of Interior
Valley Electric, Inc.
Vanderbilt University
Virginia Polytechnic Institute
Vitro Corporation
VSE Corporation
VVKR, Inc.
Wang Laboratories, Inc.
Westat, Inc.
Westinghouse Electric Corporation
Wisconsin Energy Construction Corporation
Zona Technology, Inc.

8.8 PUBLICATIONS BY SUBCONTRACTORS

AER Enterprises, "Coal Development Potential in Pakistan," in *Proceedings of the First Pakistan National Coal Conference, Karachi, Pakistan*, 1986.

Ackermann, R. A., *Free-Piston Stirling Engine Diaphragm-Coupled Heat-Actuated Heat Pump Component Technology Program, Phase IB Final Report*, ORNL/Sub/83-47985/1, April 1986.

Ackermann, R. A., *Free-Piston Stirling Engine Diaphragm-Coupled Heat-Actuated Heat Pump Component Technology Program, Phase IC Final Report*, ORNL/Sub/85-47985/1, September 1986.

Aldrich, T. M., and C. E. Easterly, *A Handbook of Epidemiological Methods with Special Emphasis on ELF Electromagnetic Fields*, ORNL-6237, Oak Ridge National Laboratory, November 1985.

Andrews, J., et al., *Optimized Ground Coupled Heat Pump Design Phase I Final Report*, BNL-38869, Brookhaven National Laboratory, October 1985.

Applied Management Sciences, Inc., *Editing Assessment for the Weekly Systems of the Petroleum Supply Division*, Jan. 31, 1986.

Applied Management Sciences, Inc., *SD Triennial Frames Update (Final Report) (Revised)*, Jan. 7, 1986.

Applied Sciences Group, Inc., *Return on Investment Analysis of Engineering Change Proposals During November 1985*, ORNL/Sub/62-43190/1, Oak Ridge National Laboratory, January 1986.

Applied Sciences Group, Inc., *Return on Investment Analysis of Engineering Change Proposals During December 1985*, ORNL/Sub/62-43190/2, Oak Ridge National Laboratory, January 1986.

Applied Sciences Group, Inc., *Return on Investment Analysis of Selected Engineering Change Proposals*, ORNL/Sub/62-43190/3, Oak Ridge National Laboratory, January 1986.

Applied Sciences Group, Inc., *Return on Investment Analysis of Various Engineering Change Proposals & Engineering Program Notices*, ORNL/Sub/62-43190/4, Oak Ridge National Laboratory, January 1986.

Applied Sciences Group, Inc., *An Evaluation of "Ejection Associated" Neck Injuries*, ORNL/Sub/62-43190/5, Oak Ridge National Laboratory, July 1986.

Applied Sciences Group, Inc., *Review of the Booklet on AAES "Ilites" Program*, ORNL/Sub/62-43190/6, Oak Ridge National Laboratory, July 1986.

Applied Sciences Group, Inc., *Quantitative Techniques for AAES Applications*, ORNL/Sub/62-43190/8, Oak Ridge National Laboratory, July 1986.

Bales, E. L., *Building Materials Research Agenda*, ORNL/Sub-97333/1, Oak Ridge National Laboratory, April 1986.

Birdwell, J. D., D. A. Castanon, and M. Athans, "On Reliable Control System Designs," *IEEE Trans. Systems, Man, and Cybernetics*, Sept./Oct. 1986.

Birdwell, J. D., J. R. B. Crockett, and J. R. Gabriel, "Domains of Artificial Intelligence Relevant to Systems," *Proceedings of the 1986 American Control Conference*, June 1986.

Birdwell, J. D., and A. J. Laub, "Balanced Singular Values for LQG/LTR Design," *Proceedings of the 1986 American Control Conference*, June 1986.

Birdwell, J. D., and K. Fung, "A Matrix Language to Communicate Between PROLOG and FORTRAN," in *Proceedings: The Eighteenth Southeastern Symposium on Systems Theory*, University of Tennessee, Knoxville, Tenn., Apr. 7–8, 1986.

Birdwell, J. D., et al., "Expert Systems Techniques in a Computer-Based Control System Analysis and Design Environment," *Proceedings of the 3rd IFAC Symposium on Computer Aided Design in Control and Engineering Systems*, September 1986.

Blanchard, J. P., *Corona Effects on a Conducting Wire in an HEMP Environment*, Air Force Weapons Laboratory Interaction Notes Series, October 1985.

Bloemer, M. J., J. P. Goudonnet, D. R. James, R. J. Warmack, T. L. Ferrell, E. T. Arakawa, and T. A. Callcott, "Light Emission from Metal-Insulator-Metal Structures Biased Near Breakdown Voltages," in *Conference Record of the 1986 IEEE International Symposium on Electrical Insulation*, IEEE Publication Services, New York, 1986.

Bloemer, M. J., R. J. Warmack, D. R. James, and T. L. Ferrell, "Enhanced Light Emission and Microstructured Tunnel Junctions," p. 1170 in *Bull. Am. Phys. Soc.*, Annual Meeting of the Southeastern Section of the American Physical Society, Williamsburg, Va., Nov. 20–22, 1986.

Boggs, D. L., and W. F. Stoecker, *Performance and Simulation of Once-Through and Separating Cycles Using Refrigerant Mixtures*, ORNL/Sub/81-7762/5&01, Oak Ridge National Laboratory, June 1986.

Braun, A. T., "Braun Engine/Compressor as Tested for Heat Pump Application—An Update," *ASHRAE Trans.* 92(2B), 153–59 (1986).

Burke, J. C., et al., *Summary and Evaluation of Field Performance Data on Unitary Heat Pumps*, ORNL/Sub/85-00219/1, Oak Ridge National Laboratory, April 1986.

Canwright, G. S., and D. M. Kroeger, "Effects of Microadditions on Cerium on the Magnetic Properties of $Fe_{80}B_{16}S_{12}C_2$ Metallic Glass," *MAG-22* (3), 182–87 (May 1986).

Canwright, G. S., and D. M. Kroeger, "Magnetic Domain Structures in Cerium-Doped $Fe_{80}B_{20}$, $Fe_{80}B_{16}S_{12}C_2$, and $Fe_{78}B_{13}Si_9$ Glassy Ribbons," *Materials Research Society Symposium Proceedings* 58, 159–62 (1986).

Chang, G. R., and J. D. Birdwell, "An Interface Language for Symbolic Programming," in *Proceedings: The Eighteenth Southeastern Symposium on Systems Theory*, University of Tennessee, Knoxville, Tenn., Apr. 7–8, 1986.

Chatterjee, Samprit, *Independent Expert Review of "An Assessment of the Quality of Selected U.S. Consumption Data,"* Oct. 8, 1985.

Childs, K. W., *The Use of Roof Temperature Modeling to Predict Necessary Conditions for Locating Wet Insulation with Infrared Thermography*, K/CSD/TM-58, Oak Ridge Gaseous Diffusion Plant, November 1985.

Computer Sciences Corporation, *Revised Conversions Training Instructor's Material*, Oct. 1, 1985.

Dempsey, B., *Mathematical Modeling of Whole Roof System Performance*, ORNL/Sub-43122/1, Oak Ridge National Laboratory, January 1986.

Dempsey, B., *Thermal and Hygric Roof (THR) Model Program*, ORNL/Sub-43122/2, Oak Ridge National Laboratory, January 1986.

Dougall, R. S., G. M. Freedman, R. W. Osborne, and D. L. Mohre, *Monitoring of Residential Groundwater-Source Heat Pumps in the Northeast*, ORNL/Sub/80-7985/1, Oak Ridge National Laboratory, March 1986.

ESG Associates, Inc., *Coal Distribution Information Requirements Review*, Feb. 21, 1986.

ESG Associates, Inc., *Electric Power Generation Cost Comparison: Coal Steam vs Natural Gas Combined Cycle*, Mar. 24, 1986.

ESG Associates, Inc., *Summary of Cogeneration, Small Power Production, and Industrial Power Production Data Needs*, Mar. 17, 1986.

ESG Associates, Inc., *Summary of Research on Typical vs Actual Electric Bills and Weighting of Commercial and Industrial Electric Bills*, Jan. 1, 1986.

ESG Associates, Inc., *Summary of Typical Electric Bills Research*, Oct. 31, 1985.

Flores, F., P. M. Echenique, and R. H. Ritchie, "Energy Dissipation in the Scanning Tunneling Microscopy of Metals and Insulators," p. 339 in *Conference Record of the 1986 IEEE International Symposium on Electrical Insulation*, IEEE Publications Services, New York, 1986.

Frank, H. J., *Independent Expert Review of EIA Energy Consumption Series State-of-the-Data Report: Findings and Recommendations*, Oct. 7, 1985.

Fung, K., and J. D. Birdwell, "An Interface Language for Symbolic Programming," in *Proceedings: The Eighteenth Southeastern Symposium on Systems Theory*, University of Tennessee, Knoxville, Tenn., Apr. 7–8, 1986.

Glicksman, L. R., and A. G. Ostrogorsky, *Effective Conductivity of Aging Polyurethane Foam*, ORNL/Sub-9009/1, Oak Ridge National Laboratory, February 1986.

Glicksman, L. R., and A. G. Ostrogorsky, *Aging of Polyurethane Foams, The Influence of Gas Diffusion on Thermal Conductivity*, ORNL/Sub-9009/2, Oak Ridge National Laboratory, August 1986.

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8.9 INVITED SPEAKERS

Date	Subject	Speaker
	1985	
October 4	U.S. Energy Trends: An Overview	Hans Landsberg, Senior Fellow, Resources for the Future, Washington, D.C.
October 8	Genetic Algorithms and Applications to Machine Learning	David Goldberg, University of Alabama
October 14	Current Research at the Swedish Institute for Building Research	M. D. Lyberg, Research Scientist, Swedish Institute for Building Research
October 17	Scale and Complexity in Risky Systems	Peter James, Warwick University, United Kingdom
November 7	Disaster Research in West Germany	Wolf Dombrowsky, Professor, Kiel University, Kiel, West Germany
November 13	Knowledge-Based Systems and Their Applications	E. A. Feigenbaum and B. G. Buchanan, Stanford University, R. Davis, Massachusetts Institute of Technology, M. Fox, Carnegie-Mellon University
November 13	Disaster Research in the Federal Republic of Germany	Wolf R. Dombrowsky, Sociology Department, Kiel University

8.9 INVITED SPEAKERS (continued)

Date	Subject	Speaker
November 20	The Role of Science in Environmental Policy Decisions	Milton Russell, Assistant Administrator for Policy, Planning, and Evaluation, Environmental Protection Agency
November 21	Genetic Algorithms for Machine Learning and Search	John J. Grefenstette, Vanderbilt University
	1986	
January 13	Some Applications of Logic in Artificial Intelligence	Dr. Wiktor Marek, University of Kentucky
January 27	Equational Dependencies for Relational Databases	Dr. Joel Berman, Dept. of Mathematics, Statistics, and Computer Science, University of Illinois
February 10	Public Concern About Industrial Hazards	Pieter Jan Stallen, TNO-Apeldoorn, The Netherlands
February 11	Public Anxiety About Industrial Hazards	Dr. Pieter J. Stallen, Research Associate, Centre for Technology & Policy Studies, TNO-Apeldoorn, The Netherlands
February 14	Rural Electrification in Lesser Developed Countries	Mark Gellerson, Southern Illinois University and U.S. Agency for International Development
February 18	The Political Economy of Fiscal Decentralization in Developing Nations	Dr. Roy Bahl, Maxwell Professor of Public Finance, The Maxwell School, Syracuse University
February 20	Inverse Problems and Parameter Estimates	James V. Beck, Professor of Mechanical Engineering, Michigan State University

8.9 INVITED SPEAKERS (continued)

Date	Subject	Speaker
February 24	Information Retrieval, Fuzzy Sets, and Artificial Intelligence: Are They Cooperative with Each Other?	Dr. James C. Bezdek, Department of Computer Science, University of South Carolina
February 24	Structural Learning in Connectionist Systems	Dr. Andrew G. Barto, Department of Computer and Information Science, University of Massachusetts, Amherst
March 3	On the Fast Parallel Algorithms	Dr. Marek Karpinski, Dept. of Computer Science, U. of Bonn, W. Germany, and Mathematical Science Research Institute, U. of California, Berkeley
March 3	Simple Programming Language Equivalent to Petri Nets	Dr. Wlodzimierz Kwasowiec, Polish Academic of Sciences, Institute of Computer Science
March 10	Unnormalized Relational Structure	Dr. Patrick C. Fischer, Dept. of Computer Science, Vanderbilt University
March 11	Data Systems R&D Program Seminar: "An Artificial Intelligence Approach to Job-Shop Scheduling"	Mark Fox, Carnegie-Mellon University
April 10	IEF—Programming Without Programmers	Phil L. Passmore, Information Systems & Services, Texas Instruments, Inc.
April 11	Cultural Factors in Computing Environments	Jonathan L. Gross, Professor of Mathematical Statistics, Department of Computer Science, Columbia University
April 11	On Concepts of Conceptual Modelling	Elod Knuth, Computer & Automation Institute, Hungarian Academy of Sciences
April 14	Modalities as Lower and Upper Approximations	Dr. Helena Rasiowa, University of Warsaw

8.9 INVITED SPEAKERS (continued)

Date	Subject	Speaker
April 18	Futures Trading and Oil Market Conditions	Douglas Bohi, Senior Fellow, Resources for the Future, Washington, D.C.
April 21	Exercises in Denotational Semantics	Dr. Boris Trachtenbrot, TelAviv University, Israel, and MIT Laboratory for Computer Science
May 5	Experience in Building Expert Systems	John Bourne, Vanderbilt University Center for Intelligent Systems
May 9	Categorical Models of Process Cooperation	Dr. Alberto Pettorossi, IASI-CNR, Rome, Italy
May 12	Representing Knowledge for a System Which Knows About Software	Dr. Stan Matwin, University of Ottawa Dept. of Computer Science
May 14	Deriving a Utility Function for the Economy	George B. Dantzig, Stanford University
June 6	Empirical Tests of Dynamic Efficiency in the Crude Oil Market: An Application of Efficient Contract Theory	Knut Anton Mork, Professor, Vanderbilt University
June 9	Reliability Analysis in Water and Power Systems: Parallels and Differences	Dr. Benjamin F. Hobbs, Case Western Reserve University
June 18	Concept and Tentative Architecture for an All-Optical Digital Computer	Dr. Larry Z. Kennedy, Vice President, Applied Research, Inc.
June 26	Recent Developments in Risk-Perception Research	Dr. Brandon B. Johnson, Michigan Technical University
July 17	Democratic Decision-Making and Fiduciary Responsibility: Public Trust As A Problem in the U.S. Army's Chemical Weapons Disposal Program	David L. Feldman, Ph.D., Moorhead State University Moorhead, Minnesota

8.9 INVITED SPEAKERS (continued)

Date	Subject	Speaker
July 30	Use of a Mobile, Programmable Robot for Decontamination at West Valley, New York	Dr. Jack Saluja, President, Viking Systems International
August 7	Rapid Prototyping: An Evolutionary Approach to Application	J. Connell, Martin Marietta Aerospace, Denver Division
August 13	Assessing State Tax Incentives for Renewable Energy Installations Software Development	Stephen W. Sawyer, Ph.D., University of Maryland
September 26	Estimating the Benefits of Rural Electrification Projects in Costa Rica	Peter P. Rogers, Division of Applied Sciences, Harvard University

8.10 PATENTS AND COPYRIGHTS

8.10.1 Patents Granted in FY 1986

Title	Inventor	U.S. Patent No.	Date
Rotational Viscometer for High-Pressure High-Temperature Fluid	K. R. Carr	4,499,753	2-19-85*
Gas Hydrate Cool Storage System	M. P. Ternes	4,540,501	9-10-85*

*Omitted from FY 1985 Report (ORNL-6272).

8.10.2 Patents Granted to Subcontractors in FY 1986

Subcontractor	Title	Inventor	U.S. Patent No.	Date
Carrier Corp.	Submerged Bundle Counterflow Generator for Use in Gas-Fired Absorption Machine	R. Reimann	4,570,456	2-18-86

8.11 FINANCIAL STATEMENT AND PERSONNEL SUMMARY

The following charts provide an outline of the work of the Energy Division. The first chart is a listing of sponsors, expenditures, and commitments of the scientific staff; and the second shows a division of personnel by discipline.

ENERGY DIVISION SPONSORS, EXPENDITURES, AND COMMITMENTS OF SCIENTIFIC STAFF FOR FY 1985

Sponsor	Expend-itures[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					
Conservation and Renewable Energy					
Buildings and Community Systems	8,616	27.4	2.6	3,404	4,081
Electric Energy Systems	5,865	8.4	0.6	1,118	4,127
Geothermal	11	0.0	0.0	11	0
Industrial	538	1.5	0.2	193	183
Multi-sector	437	1.1	0.0	134	253
Solar Energy	342	2.2	0.5	283	0
State/Local Programs	422	1.8	0.0	189	127
Transportation	470	1.3	0.0	175	205
	16,701	43.7	3.9	5,507	8,976
Civilian Radioactive Waste Management	14	0.1	0.0	10	3
Defense					
Defense Waste Management	733	2.7	0.1	308	288
Materials	1	0.0	0.0	1	0
	734	2.7	0.1	309	288
Energy Information Administration	1,118	2.2	0.1	272	760
Energy Research					
Magnetic Fusion	37	0.1	0.1	26	0
Multi-program Facilities	374	2.0	0.6	306	0
Nuclear Physics	46	0.2	0.0	32	0
	457	2.3	0.7	364	0
Environmental Safety and Health	948	4.5	0.0	464	339
Federal Energy Regulatory Commission	223	0.9	0.0	107	90
Fossil Energy	308	1.0	0.3	157	64
International Affairs and Energy Emergencies					
Utility Programs	164	0.6	0.0	69	77
Nuclear Energy					
Civilian Reactor Development Program	5	0.0	0.0	0	4
Uranium Enrichment	323	0.2	0.0	31	264
	328	0.2	0.0	31	268

SPONSORS, EXPENDITURES, AND COMMITMENTS (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]		
Policy, Planning and Analysis	123	0.2	0.0	33	71
Battelle-Columbus ONWI Programs	7	0.0	0.0	6	0
Battelle Pacific Northwest Laboratory	11	0.1	0.0	7	0
Bonneville Power Administration	359	1.8	0.0	193	67
Oak Ridge Operations Office	16	0.0	0.0	6	6
Office of Scientific & Technical Information	49	0.5	0.0	48	0
Strategic Petroleum Reserve	24	0.2	0.0	18	0
Westinghouse Materials Company of Ohio	194	1.4	0.2	152	0
	660	4.0	0.2	430	73
Total DOE work	21,778	62.4	5.3	7,753	11,009
Other Federal Agencies Work					
Department of Defense					
Department of the Air Force					
Defense Security Assistance Agency	4,425	0.4	0.1	65	4,204
Engineering & Services Center	1,654	7.9	0.7	864	343
Gunter Air Force Station	195	1.3	0.0	125	0
	6,274	9.6	0.8	1,054	4,547
Department of the Army					
Assistant Comptroller of the Army	247	0.4	0.5	85	85
Civilian Personnel Center	885	1.9	0.0	205	513
Construction Engineering Research Laboratory	127	0.9	0.0	108	6
Corps of Engineers	281	1.3	0.0	159	68
Facilities Engineering Support Agency	412	1.9	0.6	321	34
Forces Command	224	1.0	0.0	118	21
Material Command	1,561	0.8	0.2	106	1,142
Munitions & Chemical Command	828	0.2	0.1	98	715
Toxic and Hazardous Materials Agency	1,362	4.0	0.7	511	233
	5,927	12.4	2.1	1,711	2,817
Department of the Navy					
Assistant Comptroller of Financial Management System	164	0.9	0.1	97	2
Commander Naval Reserve	1,021	0.2	0.0	19	956
David Taylor Naval Ship R&D Center	171	0.7	0.1	85	64
Marine Corps	2,305	0.7	0.1	87	2,118
Naval Air Engineering Center	1,080	0.1	0.0	9	1,040
Naval Air Systems Command	1,237	0.2	0.0	65	1,134
Naval Aviation Logistics Center	6,748	2.2	1.7	449	6,041
Naval Civil Engineering Laboratory	30	0.2	0.0	26	0

SPONSORS, EXPENDITURES, AND COMMITMENTS (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]		
Naval Management System Support	10,609	8.3	0.0	719	8,823
Naval Material Command	346	2.2	0.0	224	30
Naval Military Personnel Command	10,555	11.7	0.6	1,158	7,981
Naval Regional Data Automation	7,754	2.5	0.2	254	6,489
Naval Sea Support Center, Atlantic	372	0.1	0.0	4	347
Naval Sea System Command	4,183	1.5	0.2	227	3,710
Naval Supply Systems Command	1,236	1.2	0.0	110	634
Naval Weapons Engineering Support	342	0.1	0.1	24	297
Navy Finance & Accounting Center	1	0.1	0.0	7	0
	48,154	32.9	3.1	3,564	39,666
Joint Agencies:					
Assistant Secretary of Defense—Energy Programs	21	0.1	0.0	14	0
Military Sealift Command	1,122	0.9	0.1	91	967
Military Traffic Management Command	1,613	6.6	0.2	652	190
Office of Joint Chiefs of Staff	5,287	0.2	0.1	104	4,937
	8,043	7.8	0.4	861	6,094
Subtotal DOD work	68,398	62.7	6.4	7,190	53,124
Department of Education	227	0.0	0.0	0	222
Department of the Interior	6	0.0	0.0	6	0
Department of Justice	349	0.0	0.0	0	293
Department of Labor	27	0		12	0
Department of State—Agency for International Development	1,991	5.3	0.6	626	961
Department of Transportation	365	1.7	0.0	168	90
Environmental Protection Agency	1,969	4.8	0.6	573	729
Federal Emergency Management Agency	1,122	2.6	0.0	307	507
General Services Administration	28	0.0	0.2	26	0
National Aeronautics and Space Administration	75	0.0	0.0	0	75
Nuclear Regulatory Commission	788	1.7	1.2	378	235
Tennessee Valley Authority	181	0.8	0.0	118	1
U.S. Customs Service	358	0.0	0.0	0	351
Total other federal agencies work	75,884	79.7	9.0	9,404	56,588

SPONSORS, EXPENDITURES, AND COMMITMENTS (continued)

Sponsor	Expenditures[a] (10³ $)	Scientific staff (person-years) Energy Division	Scientific staff (person-years) Other divisions[b]	Direct person-year costs[c] (10³ $)	Subcontract costs with overhead[d] (10³ $)
Private Organizations Work					
Borg-Warner Corporation	19	0.1	0.0	15	0
Electric Power Research Institute	133	1.2	0.0	103	0
Institute Electrical & Electronics Engineering, Inc.	5	0.0	0.0	0	0
Martin Marietta Corp.—Denver Aerospace	7	0.0	0.0	7	0
National Home Builders Association	54	0.0	0.0	0	2
Pacific Power & Light Company	99	0.8	0.0	80	0
Puget Sound Power & Light Company	17	0.1	0.0	17	0
Total private organizations work	334	2.2	0.0	222	2
Total non-DOE work	76,218	81.9	9.0	9,626	56,590
Total DOE work	21,778	62.4	5.3	7,753	11,009
Total Energy Division work	97,996	144.3	14.3	17,379	67,599

[a]The 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; etc.

[b]Includes the following research divisions: Analytical Chemistry, Biology, Chemical Technology, Engineering Physics and Mathematics, Engineering Technology, Environmental Sciences, Fusion Energy, Health and Safety Research, and Metals and Ceramics.

[c]Includes technical staff labor costs for Energy Division and other research and support divisions and Laboratory overhead.

[d]Includes Laboratory overhead where it applies but excludes the subcontract incremental tax of $220,213 charged to the Energy Division during FY 1986. This tax is to pay for the costs of procurement, auditing, and accounting.

ENERGY DIVISION PERSONNEL BY DISCIPLINE
[Full-time Equivalents (FTEs)]
September 1986

Discipline	IAAS*	EEAS	DAS	DSRS	ERRS	P&P	Division Adminis-tration	Total (FTEs)
Technical Professional								
Social sciences								
Anthropologists	2.0							2.0
Architects					0.5			0.5
Economists	1.0	14.5						15.5
Geographers	1.0	6.0		4.0		1.0	1.0	13.0
Planners	1.0			1.0				2.0
Political scientists	2.0							2.0
Psychologists				1.0				1.0
Science education					1.0			1.0
Sociologists	1.5			1.5				3.0
Total social sciences	8.5	20.5		7.5	1.5	1.0	1.0	40.0
Physical and life sciences								
Biologists	2.0		3.0					5.0
Chemists	4.0		2.0	1.0				7.0
Ecologists	1.0							1.0
Geologists	4.0							4.0
Meteorologists	3.0							3.0
Physicists	1.0		1.0		4.0	1.0		7.0
Total physical and life sciences	15.0		6.0	1.0	4.0	1.0		27.0
Engineering sciences								
Chemical engineers	3.0		1.0	1.0	4.0		1.0	10.0
Civil engineers	1.0	1.0						2.0
Electrical engineers	2.0		1.0	2.0	6.0			11.0
Engineering physicists					1.0			1.0
Engineering scientists	1.0				2.0			3.0
Environmental engineer	1.0							1.0
Industrial engineers			1.0					1.0
Mechanical engineers	5.0	1.0	3.0	2.5	20.0	1.0		32.5
Nuclear engineers					1.0			1.0
Other					1.0			1.0
Total engineering sciences	13.0	2.0	6.0	5.5	35.0	1.0	1.0	63.5
Data systems								
Computer sciences	1.0	1.0	8.0	2.0				12.0
Mathematicians/statisticians	2.0	1.0	5.0	9.0	1.0			18.0
Operations research			1.0	1.0				2.0
Systems analysts				1.0				1.0
Other	1.0		2.0	1.0				4.0
Total data systems	4.0	2.0	16.0	14.0	1.0			37.0
Total technical professionals	40.5	24.5	28.0	28.0	41.5	3.0	2.0	167.5

ENERGY DIVISION PERSONNEL BY DISCIPLINE (continued)

Discipline	IAAS[a]	EEAS	DAS	DSRS	ERRS	P&P	Division Adminis-tration	Total (FTEs)
				Administrative and Technical Support				
Accounting clerks			1.0				3.0	4.0
Administrative assistants							1.0	1.0
Secretaries	8.5	6.0	7.0	6.0	9.0	0.5	4.0	41.0
Technicians	3.0	1.5	3.0	3.0	5.0	1.0		16.5
Total administrative and technical support	11.5	7.5	11.0	9.0	14.0	1.5	8.0	62.5
Total	52.0	32.0	39.0	37.0	55.5	4.5	10.0	230.0

[a]IAAS = Integrated Analysis and Assessment Section; EEAS = Energy and Economic Analysis Section; DAS = Data and Analysis Section; DSRS = Data Systems Research Section; ERRS = Efficiency and Renewables Research Section; and P&P = Programs and Planning.

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July 1, 1986

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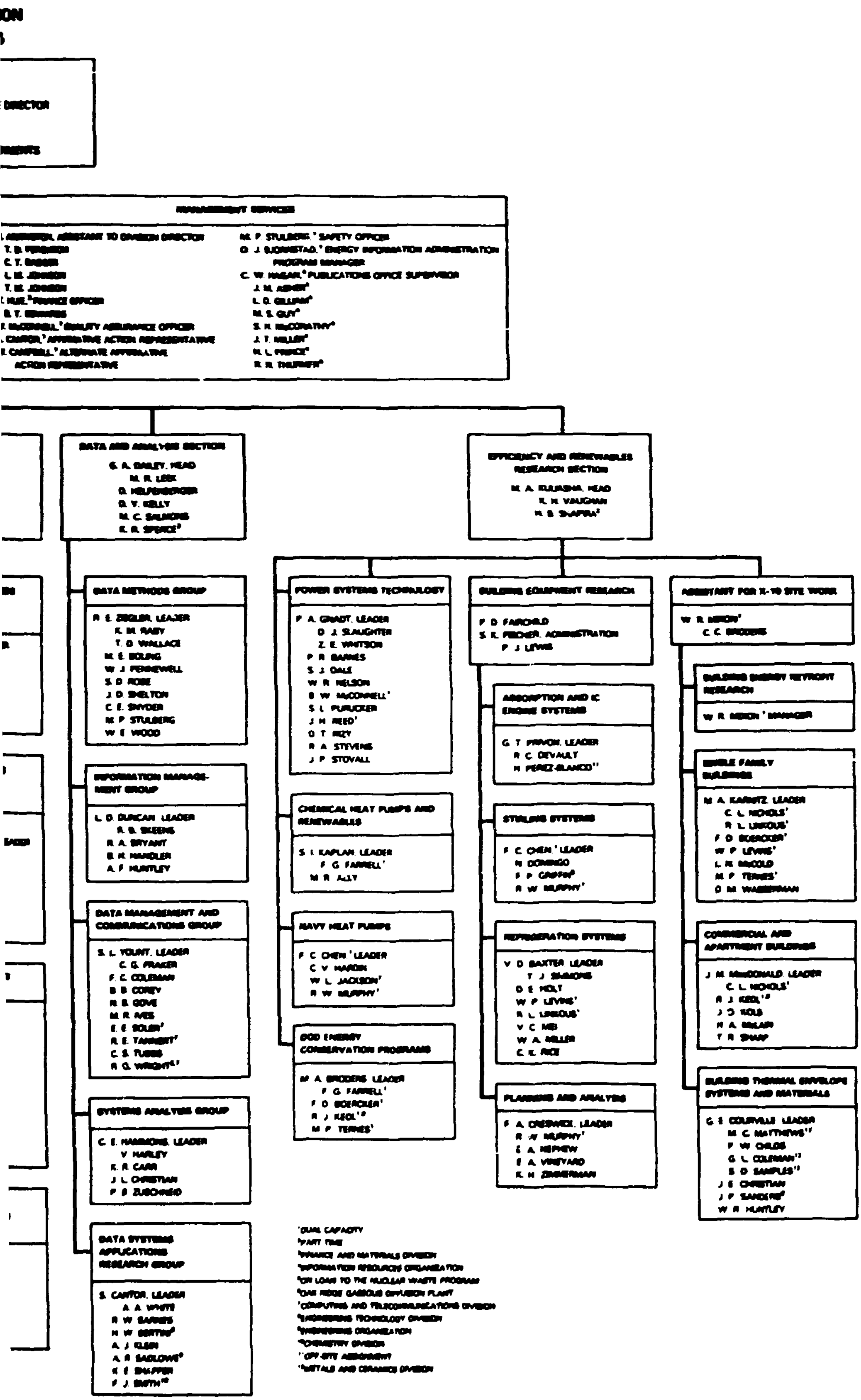

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