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BPA

End-Use Load and Conservation Assessment Program

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ELCAP

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END-USE LOAD AND CONSERVATION ASSESSMENT PROGRAM PAPERS PRESENTED AT THE ELECTRIC POWER RESEARCH INSTITUTE'S COMMERCIAL END-USE METERING WORKSHOP

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Prepared By
Pacific Northwest Laboratory
Richland, Washington 99352
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

PREFACE

The End-Use Load and Conservation Assessment Program (ELCAP) is an hourly end-use metering experiment sponsored by the Bonneville Power Administration (BPA) and managed by Pacific Northwest Laboratory (PNL). The program began in September 1983. By January 1985, the project staff had begun evaluating the experience gained from a series of pilot installations in commercial and residential buildings, the full-scale installation in the residential sector had just begun, and the central data acquisition facility had demonstrated the ability to collect information from a modest number of sites.

At this time, several members of the ELCAP staff were invited to participate in a commercial end-use metering workshop conducted by Synergics Resources Corporation (SRC) for the Electric Power Research Institute. With the encouragement of Phillip Windell and Michael Warwick of BPA, a series of papers describing the basic features of ELCAP were prepared and presented at the workshop, which was held January 15-16, 1985 in Seattle, Washington.

The six papers presented on ELCAP are collected and reprinted here as a single document that presents both an overview of the program as well as more specific descriptions of the program's various elements: recruitment of buildings, instrumentation of the buildings, data acquisitions, data management, and data verification. These papers remain the most concise description of the functional aspects of ELCAP.

In releasing this document, we are particularly grateful to Craig MacDonald of SRC and Joe Wharton of EPRI for providing a forum for the ELCAP staff and BPA to present the basic elements of ELCAP and for permission to reprint the papers.

Section 3

AN OVERVIEW OF ELCAP

R. A. Stokes,* ELCAP Manager

ABSTRACT

The End-Use Load and Conservation Program (ELCAP) is a multi-year effort sponsored by the Bonneville Power Administration (BPA) to better understand the energy performance and conservation potential of buildings in the Pacific Northwest. ELCAP serves as an umbrella structure for a number of programs designed to meet specific research goals. Prominent among these are programs designed to evaluate the effects of the Northwest Power Council's proposed Residential Standards Demonstration Program (RSDP), to characterize auditing procedures in commercial buildings [i.e., BPA's Commercial Audit Program (CAP)], and to investigate the effects of conservation incentives and retrofit weatherization [i.e., BPA's Purchase of Energy Savings Program (PES)] . A number of structures will be subjected to detailed end-use metering in support of these programs. In addition, large samples of residential and commercial buildings in the Bonneville service territory, not participating in any of the specific programs, will be metered. These data collection efforts, while sharing a common technology and approach to data acquisition and management, have distinct research plans with different schedules, staff, and equipment requirements.

The separate projects which comprise ELCAP are briefly described, and the five subsequent papers which detail the project metering experience to date are introduced.

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* Pacific Northwest Laboratory, Richland, Washington.

INTRODUCTION

Data from a number of commercial buildings and residences will be analyzed in detail to estimate building energy requirements and energy conservation potential. The data set will facilitate the evaluation and development of improved simulation models and auditing techniques. To conduct these activities, BPA has contracted with the Pacific Northwest Laboratory (PNL) operated by Battelle Memorial Institute for the Department of Energy.

PNL has developed an end-to-end data acquisition and analysis capability for ELCAP based on a low-cost field data acquisition system (FDAS) with integrated watt-hour and meteorology sensors, a dedicated central microcomputer for routine interrogation and error checking of the FDAS's use of telephone lines and modems, and software on a VAX 11/780 super minicomputer for data base management and statistical manipulation of the data. The entire system provides a means of monitoring electrical consumption at a detailed end-use level, e.g., lighting, heating, ventilation, and air conditioning (HVAC), and refrigeration with hourly time resolution; approximately 1000 structures will be instrumented throughout the five states served by BPA.

THE SEVEN ELCAP STUDIES

ELCAP provides a management structure to coordinate data acquisition and analysis activities for seven different studies which require similar data and can take advantage of the PNL technology. They are

1. A study of 200 commercial buildings in 10 different categories located in the Seattle City Light (SCL) service area. This study is designed to augment a study of 13 commercial buildings begun by SCL in 1983.

2. A study of 40 commercial buildings distributed throughout the region participating in BPA's Commercial Audit Program (CAP). One objective of this study is to assess the accuracy of conservation savings estimates based on commercial auditing procedures.

3. A study of 27 commercial buildings distributed throughout the region participating in BPA's Purchase of Energy Savings Program (PES). The study will assess conservation savings resulting from a series of operational changes and conservation measures adopted by the predominately large and complex buildings in PES.

4. A detailed energy consumption study of residences built to conform to the performance standards proposed by the Northwest Power Planning Council. Approximately 100 new houses throughout the region will be constructed in conformance with the model conservation standards as part of the Residen-

tial Standards Demonstration Program (RSDP) and instrumented with the ELCAP field data acquisition system. The energy performance of these model conservation standards (MCS) houses will be compared in detail to that of 100 similar residences selected from a large regional sample of structures selected from the second Pacific Northwest Regional Energy Survey (PNWRES) to determine the effectiveness of the proposed building codes in achieving energy conservation.

5. A detailed energy consumption and electrical load-shape study of 500 residences throughout the Northwest selected so as to be representative of the housing stock, occupancy patterns, lifestyle, and climate in the region served by BPA. Four hundred of the residences are single-family, owner-occupied houses heated by electricity. The remaining 100 residences are selected to represent the mobile home, row house, and non-electrically space heated houses that are occupied by renters. Half of the residences in this study have wood stoves, which are used to supplement electrical space heating; these wood stoves are instrumented so as to record hourly use.

6. A study of 25 multifamily structures throughout the region. This sector presents a special instrumentation challenge because of the typical distribution of electrical panels in the structures. This sector is thought to represent one of the last remaining categories of structures relatively untouched by conservation programs to date.

7. An evaluation of the thermal performance of nine new manufactured housing units built to the Northwest Power Planning Council's residential model conservation standards. The performance of these structures will be monitored while they are unoccupied for several months before they are sold. Subsequently, they will be monitored and their performance compared to that of the 25 older mobile homes in the main ELCAP residential study. In addition to the thermal performance study, a range of indoor air quality and infiltration performance checks will be completed during the experiment.

The seven studies all share a requirement to assess the extent of conservation savings as well as any shifts in load shape which would result from some modification to the building shell or its operating strategy. The data from all seven studies will be collected into a single data base using a common format.

Any large-scale end-use metering experiment is sure to involve acquisition of a substantial quantity of data from a network of field stations over an extended period of time. Successful completion of any such project requires that several conditions are met. Data of good quality must be obtained from a high fraction of the experimental sites with few gaps in the time series records. The data must be verified and made available to analysts with a minimum of delay from its collection. The data must be organized in such a fashion as to be readily accessible to analysts in a form which permits them to address issues related to the experimental goals.

Finally, each of these conditions must be achieved at reasonable expense. Meeting these conditions is a particular challenge as the number of sites and the complexity of each installation increases. These factors require development of a data acquisition and management system that is highly automated and reliable.

Our specific goals as we approached the design of an automated data acquisition system were

- minimized unit cost of the field data acquisition system
- capability of metering complex structures requiring 40 to 50 watt-hour measurements to achieve the required end-use disaggregation
- field unit memory sufficient to retain at least one week of data between interrogations
- built-in sensor interfacing and high-speed telecommunications capability
- automated interrogation and error checking by a dedicated central micro-computer
- efficient data base management system for the hourly end-use energy consumption data and site-specific meteorology data
- compatible data base management system to provide easy reference to information on the characteristics of individual buildings and any economic or demographic data on occupants
- analysis software capable of providing easy tabular or graphic summaries of data with automation of frequently used data work-ups.

Five subsequent papers will outline in some detail the metering equipment and procedures which have been developed to carry out the ELCAP metering experiment. Section 8 by Schuster and Tomich describes the low-cost microprocessor-based field data acquisition system which was developed for the effort as well as the performance of the energy and meteorology sensors used at the field sites to gather hourly end-use and meteorology data. Section 9 by Mazzucchi and Sandusky describes the procedures used to formulate a measurement plan for each ELCAP structure. The measurement plan provides the basis for disaggregation of energy use data on many different channels into a cannonical set of end uses for residences or commercial buildings. Section 10 by Mazzucchi and Crowder provides insight into the approaches necessary to recruit commercial building owners or tenants into such a study. This paper describes our pilot study experience and the manner in which we modified our procedures in order to maximize the probability of recruiting a particular building as a function of building category. Section 12 by Pearson describes the automated data acquisition and analysis system in some detail. Section 13 by Pearson, Stokes and Crowder outlines the rather involved data verification procedures required to ensure that we are metering the particular end use specified in the measurement plan for the building. Because of the large number of structures participating in ELCAP, most of the data acquisition, data verification and quality control, and routine data analysis procedures are computerized.

At present, we are roughly midway through the installation activity required to instrument the 1000 field sites and a fifth of the way through the initial site verification and quality control activities which must be completed before archival data are gathered. Preliminary data work-ups of pilot study results are encouraging, and we are hopeful that the results of ELCAP will prove to contribute significantly to the region's electrical load research and planning activities for many years.

Section 8

ELCAP INSTRUMENTATION

G. J. Schuster and S. D. Tomich

INTRODUCTION

End-use electrical metering is a challenging experimental task, which places substantial demands on instrumentation. A well-designed data logger for end-use metering studies should have a number of characteristics:

- It should be sufficiently flexible to permit the metering of as many circuits as necessary at a given site to provide the desired level of end-use disaggregation and redundancy in measurement.
- It should permit the acquisition of data at a variety of temporal resolutions, ranging from intervals short enough to monitor the behavior of electrical equipment with short cycle times to hourly or lower resolution data collection. If possible, it should permit remote adjustment of the measurment resolution.
- It should be reliable, maintaining its performance over extended periods in the field without requiring adjustment.
- It should be sufficiently inexpensive to permit metering of a large sample of buildings at reasonable cost.
- It should have nonvolatile solid state memory and permit the remote acquisition of data.
- It should permit measurements with an accuracy at least equal to that of utility-grade meters.
- It should be capable of supporting a variety of instrumentation, including not only current and voltage sensors but also meteorological devices.

Over the past few years Pacific Northwest Laboratory has developed a series of data loggers under U.S. Department of Energy (DOE) and Bonneville Power Administration (BPA) sponsorship. The most recently completed logger, designed to meet these requirements, is currently being deployed in the End-Use Load and Conservation Assessment Program (ELCAP), an end-use metering study of 1000 residential and commercial structures in BPA's service territory. This document provides a functional description of the data logger, describing both the main hardware components and the system's software. Application of the logger to power measurements and meteorological and interior condition measurements is discussed along with experience on field performance. A table is provided showing approximate data logger, sensor, and installation costs as experienced in this study.

OVERVIEW

The data logger consists of a standard electrical enclosure that houses a triple output power supply, a telecommunications modem, a main data logger board, and a complement of power metering boards (up to eight). These components are mounted to a single back plate for ease of assembly, installation, and repair. Sensors for all metered channels as well as meteorology inputs or other devices are brought into the unit via standard techniques using conduit where necessary and other measures which may be required by local installation codes.

The main logger board contains the components which are necessary to implement data acquisition from standard meteorology inputs, the watt hour metering circuitry, and devices which require a digital interface (e.g., switch closures, alarm outputs, pulse-initiating watt meters, etc.). This board is designed around a Motorola single-chip microprocessor with additional battery-backed up memory, multiple analog and digital input channels, and a serial interface to a high-speed modem for telecommunications. The design also includes the conditioning circuits required for a complement of sensors which define a standard meteorology station.

The microprocessor contains internal erasable-programmable memory in which the scanning and interface programs are placed in microcode. Buffers enable the single-chip device to access additional battery-backed up memory for data and parameter storage as required by the application. For this type of data logging the microprocessor is programmed to telephone the data collection computer after power failure and preserve the memory during the power outage. In most cases the microcode can handle a variety of situations in which the modem is used effectively. Since the microprocessor uses a standard serial interface to the modem, the same interface can be used on site during installation and checkout procedures.

Analog channels are supplied for data acquisition by the microprocessor in banks of 16 channels for a total of 64 analog channels. These analog channels are used to input the electrical power metering channels for conversion to digital form. A typical installation may use up to 8 channels for meteorology inputs and 56 channels for power measurements. These analog inputs can also be used for other monitoring devices such as gas flow and pressure meters.

Digital inputs are also provided, which allow the system to acquire data from a wide range of equipment requiring this type of interface. Up to 48 discrete inputs can be monitored, and these may come from wind speed instruments, pulse-initiating watt meters, switch closures, or other digital devices with bi-level signals. Many of these channels may be configured as outputs to drive relays, indicators of device status, or indicators of alarm conditions.

Watt-hour metering is performed by customized analog circuitry, which was designed for this application and provides analog outputs to the main logger board. Step-down voltage tranformers sample each voltage of an electrical panel and UL-recognized current transformers are used on each desired breaker and main feed. Each watt-hour board has the capability to handle eight separate electrical power measurements, and each channel can be individually configured for the correct phase voltage and circuit capacity.

The individually metered channels compute power by performing a real-time multiplication of voltage and current and integrating the result into one-second intervals. Using this method, the power factor for any particular load is already accounted for by the circuit. Since the voltage and current phase relationship is not assumed constant and the multiplication with averaging occurs in real time, the one-second samples provide extremely high resolution and accuracy compared to typical electrical metering approaches. The watt-hour board outputs are scanned by the microprocessor, which accumulates their values into a data record whose size can be programmed remotely.

Testing on the unit occurs at several stages throughout the assembly process. Each component is tested separately, and only pretested parts are used in the final assembly. Once the unit is assembled, it undergoes still another functional check before it receives a final calibration on all input channels. The units are then tagged, serial numbered, and tracked with their respective calibrations traceable to sub-component level, time and date, as well as manufacturing lot numbers.

Data acquisition software for the system is written in microcode to provide a high-speed, compact package to ensure ultimate reliability in the system. The data logger uses a series of commands to converse with the interrogating computer system over standard telephone lines. Data are summed from the analog channels once per second and digital channels are scanned 300 times per second, which provides monitoring of digital signal rates of up to 75 Hertz. The software allows the interrogation computer to send sets of parameters to designated sections of memory for setting the functions of individual channels, data record size, number of channels activated, and other useful parameters such as time and date.

During setup the data logger is usually set to very high data resolution, such as 5-minute data record length, which enables system checkout and verification of channel signatures. Since these parameters can be set remotely, the system can be reprogrammed for larger data records once the installation is operational. Time and date data are also kept in the data logger as the software maintains a system clock based on one-second resolution to an accuracy of a few minutes per month. This design feature enables the unit to provide time series data and also to accurately record power outages and allow reconstruction of other timed events.

Routine data collection simply requires the data interrogation computer to dial the data logger's dedicated phone line for retrieval. Once contact is established via the system's modem, several commands are interchanged for site verification, which includes checking the system clock and parameters for data collection. The data interrogation computer then retrieves entire blocks of data, which are checked during data transmission for errors. Once data are collected, the system is released from the telecommunications to continue collecting individual records. During all data collection intervals, the microprocessor on the the data logging board continues to scan its preset channel group and the discrete data acquisition is maintained.

This data logger is proving to meet most of the design requirements enumerated earlier in a reasonably satisfactory fashion. To date, field reliability has been excellent, and fabrication costs are relatively low. During the course of over 300 installations spanning a 9-month period, very few hardware failures have been logged. Nearly all failures occurred at the time of equipment installation and generally can be related to mishandling, which caused blown fuses or shorted channels. Using standard handling practices for this type of equipment would have resulted in only one failure of the hardware to date, and this was due to a faulty memory cell in a commercial RAM package.

We have experienced a number of telecommunications problems, which were generally attributable to the varying quality of telephone lines used in the study. Over

20 different telephone companies' networks are used, and problems vary from noisy lines and attenuated signals to poor connections. Fortunately, this field data acquisition system incorporates a high/low speed modem, so where poor connections are noted, some units are switched to lower data rates to enhance data capture. Overall system reliability has been quite good to date with current equipment accumulating well over 1 million hours of operation or the equivalent of 145 unit/years total.

Costs for the data logger varies dependent on the number of power metering channels desired and the complement of other sensors required for the application. The following table outlines the equipment used in the study for residential as well as commercial installations and the additional meterology sensors distributed throughout the four-state region.

	Costs
Power metering	
Basic data logger with 16 power metering channels	\$2700.00
Additional power metering channels in groups of 8	280.00
Current transformers, one for each main or breaker	18.00
Residential logger with 16 channels and current transformers	2988.00
Commercial logger with 56 channels and current transformers	5108.00
Meteorology sensors	
Wind speed and direction, 0 to 100 mph, 0 to 360 deg	200.00
Indoor air temperature, thermistor type, 0 to 30 ± 0.5°C	50.00
Outdoor air temperature, solid state, -50 to 60 ± 1.5°C	80.00
Relative humidity, 0 to 100% ± 5%	260.00
Solar illuminance, pyranometer, 0 to 1700 W/m^2	175.00
Woodstove, thermocouple, 0 to 1150 ± 20°C	50.00
Complete meteorology station including wood stove sensor	815.00

The above costs do not include installation of the equipment, which can range from less than \$1000 for residential sites to \$5000 for commercial sites. The installation costs vary from site to site dependent on subcontractor used, electrician rates, and installation complexity. Overall the costs per metered channel remained a factor of 2 below currently available commercial watt metering equipment, and in some cases a factor of 10 or more.

SUMMARY

Electrical end-use metering and analysis provides information for forecasting electrical loads, modeling in regional studies, identifying conservation options, studying energy efficiency, and forecasting energy peak demand. The data logger developed for the BPA application provides low cost per channel power metering as well as flexibility in meteorology sensing. This type of technology represents a state-of-the-art technique as applied to power metering which can be used for small studies or large, regional-scale projects in a variety of structures and locations. By incorporating telecommunications as the method of data retrieval, the network of data loggers allows automated collection, processing, and analysis of electrical end-use data.

Section 9

ELCAP: MEASUREMENT PLANS AND EQUIPMENT INSTALLATION

Richard P. Mazzucchi*
William F. Sandusky*
Marc Schuldt+

INTRODUCTION

Pacific Northwest Laboratory (PNL) will be involved in installing metering equipment in approximately 200 commercial buildings in the Seattle, Washington, area. This effort is one part of the End-Use Load and Conservation Assessment Program (ELCAP) that PNL is conducting for the Bonneville Power Administration (BPA).

Under ELCAP various well-defined activities will be completed to ensure that all the metering equipment has been installed properly, functions in the desired manner, and provides accurate energy performance data. This last activity requires that a measurement plan be generated. Since experience with the collection of actual energy performance data from commercial buildings is limited to date, the measurement plan development procedures were evaluated in a set of pilot buildings prior to finalization. Precise documentation of how measurement plans are configured and implemented is essential to ensure adequate quality control.

The measurement plan is important to the installation process in that it provides a 'road map' to the installation contractor. The plan tells the contractor which circuits are to be monitored, where the panels are in the building, how much equipment will be needed to complete the work (i.e., number of current transformers, amount of conduit, and multipair wire), and of any obstacles that may impede the installation effort. Other activities associated with installation activities include installing the equipment and performing communication checks and equipment verification checks. The relationship between these activities and other associated tasks is illustrated in Figure 9-1.

*Pacific Northwest Laboratory, Richland, Washington.
+United Industries Corp., Bellevue, Washington.

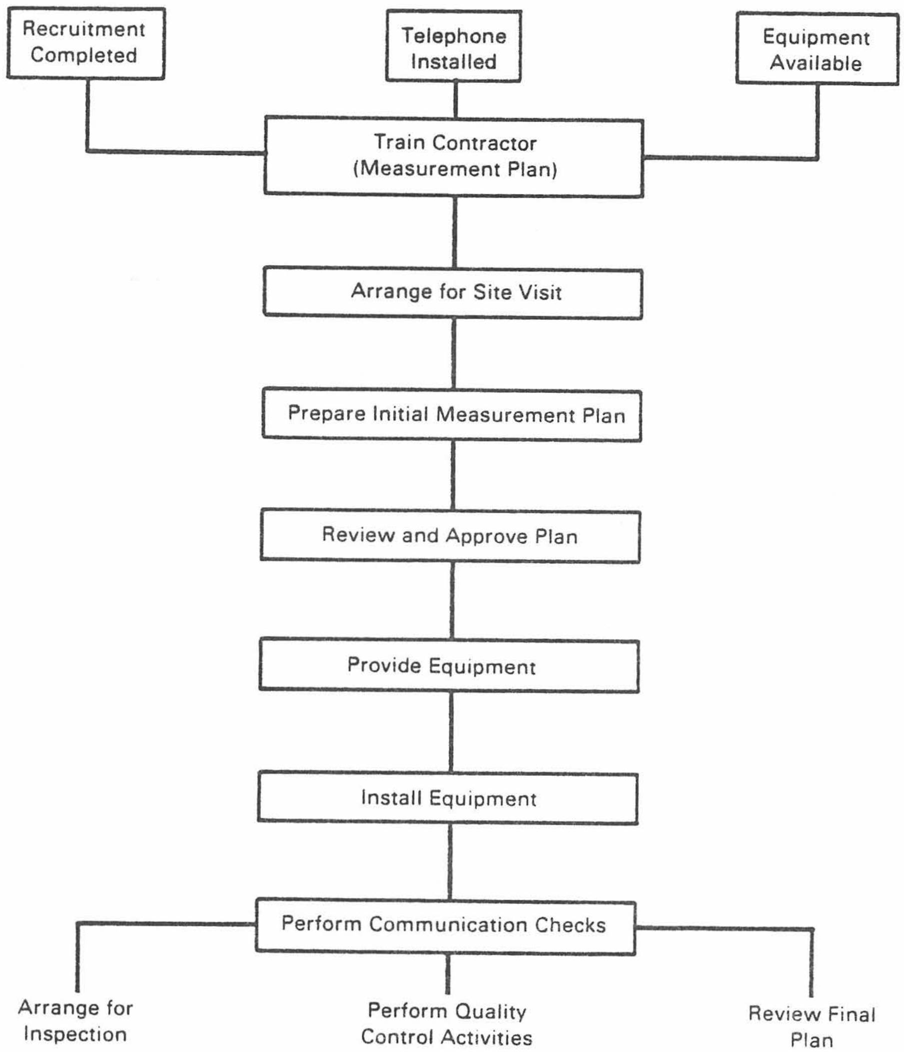

Figure 9-1. Installation Process

This paper begins with an overview of the ELCAP objectives, which lead to specific measurement plan requirements. These requirements are reviewed, and specific measurement plan criteria are established. The procedures used to develop a measurement plan for a particular building are described. A discussion of various installation activities is provided, along with problems associated with the measurement plans in terms of installation activities. Also provided is the average contractor cost for developing measurement plans and installing metering equipment in the pilot study buildings. Finally, changes made to various installation-related procedures as a result of the pilot study are highlighted.

MEASUREMENT OBJECTIVES

The primary objective of ELCAP efforts is to compile an accurate and complete data base of hourly electrical consumption by major end uses for a stratified sampling of buildings along with information on key building characteristics. We will use this data to identify when, how, and where buildings use electricity, and to begin to establish building energy use cause and effect. This information is of value for forecasting utility loads and assessing conservation potential as well as developing and evaluating methods to estimate building energy usage.

Although the primary focus of the project effort is to understand electrical energy usage, we may need to measure nonelectric fuel consumption to fully understand building energy performance. Specific provisions to provide, in a cost-effective manner, the desired data through one-time tests and electrical load proxies are desirable. Pacific Northwest Laboratory is also trying to negotiate with fossil fuel suppliers so that fossil fuel usage can be measured directly with our metering equipment.

To understand energy use cause and effect and estimate energy conservation potentials, we need to know internal and external climatic conditions. Cost considerations limit the degree to which these factors can be measured; however, all buildings will have at least one interior temperature sensor, and a subset of buildings will be equipped with a microclimate station. This station will record solar intensity, temperature, and wind speed and direction.

An energy audit form, an electrical service panel survey, and a measurement plan will be completed for every building instrumented. The energy audit forms document the electrical service, measurement strategy, and building characteristics information needed to analyze the project data. Installation contractors will document the electric service characteristics on panel survey forms and identify the number and location of sensors required to isolate energy end uses. Pacific Northwest Laboratory will review and approve the measurement plan before beginning installation activities.

To achieve the aforementioned objectives in a timely and efficient manner, detailed measurement guidelines will be used in the full sample study. The guidelines establish the minimum requirements for data collection and lead to a determination of the suitability of a candidate site for participation. These guidelines are not provided in this paper, but may be obtained from the authors.

MEASUREMENT CRITERIA

This section discusses criteria for the following three measurements: 1) energy use, 2) interior temperature, and 3) microclimate.

Energy Use Measurement

The rate of electrical consumption is to be measured for each major end use and specific categories of use for individual building groupings and case studies (Table 9-1). This is to be accomplished to the maximum extent possible by installing 56 or fewer current transformers within the electric service panels and switchgear. On the average, a baseline of 24 current transformers is expected.

In buildings with nonelectric fuels, special consideration must be given to the placement of electrical sensors to serve as proxies to apportion nonelectric fuel usage over the respective measurement period. By this we mean that electrical circuits dedicated to equipment that is fueled by nonelectric energy should be instrumented where possible to provide a pattern of equipment usage. Examination of this pattern in conjunction with the billing records for nonelectric fuels can yield valuable insight into building energy performance.

For instrumentation to yield worthwhile data measurements, it must reliably allow energy consumed for heating, ventilation, and air-conditioning (HVAC) equipment to be separated from lighting and other uses. If these broad end-use categories cannot be separated to within an accuracy of plus-or-minus 5% of the estimated energy consumption with the initial sensor allotment, the building shall be recommended for rejection.

The goal of the measurement plan is to provide the greatest end-use definition with the fewest number of sensors. The first priority is to ensure that three broad end-use categories are isolated (HVAC, lighting, other). The second priority is to further sort these groups into more detailed end-use groupings. A third priority is to measure end-use consumption within particular building zones (i.e., storage, office, showroom areas) where circumstances permit. The first priority is required for building selection, the second priority is highly desired and expected to be accomplished where possible, and the third is desired where project resources and building characteristics permit.

To ensure the accuracy of logger measurements, a sum-check rule must be employed. This rule requires that energy supplied to and drawn from monitored panels be measured.

Table 9-1

ELCAP MEASUREMENT PLAN REQUIREMENTS

	Building Type	Major End Uses																	
		HVAC				Lighting		Other											
								Major Equipment											
		Space Heat	Ventilation	Auxilliaries	Space Cool	Interior	Exterior	Refrigeration	Water Heating	Receptacles	Vert. Transport	Food Preparation	Mat. Handling	Computers	Rec. Equipment	Laundry Fac.	Lab Equipment	Shop Equipment	Spec. Equipment
Major Groupings	Dry-Good Retail					●	●			●	●								
	Grocery					●	●	●	○	●									●
	Office					●	●			●	●	○		●			○		
	Restaurant		●			●	●	●	●	●		●				○			
	Schools					●	●	○	○	●		○		●	●	●	●	●	
	Warehouse					●	●	○		●	●		●					●	
Case Studies	Auto Repair					●	●			●			●					●	●
	Bakeries		●			●	○	●	●	●		●	●						●
	Churches					●		○	○	●		○			●	○			
	Clinics					●		○	●	●						●	●		●
	Hospitals		●			●	●	●	●	●	●	●	○	○		●	●		●
	Hotel/Motel					●	●		●	●	●				●	●			
	Laboratories		●			●	○	○	●	●			○	○		○	●		●
	Laundries		●			●	○		●	●			●			●			
	Libraries					●				●				○					●
	Movie Theatres					●	●		●	●		○							●
	Museums					●				●									
	Nursing Homes					●	●	●	●	●	●	●			●	●			●
	Police Station					●				●									●
	Post Office					●				●			●	○					●
	Public Assembly					●	●		●	●		○			●				●

● Required in all cases

○ Required if load is significant

With this practice we are able to verify that the sum of power delivered by a panel is equal to that supplied. Thus, if a sensor fails, application of the sum check procedure (program) will reveal a problem exists and permit focused corrective action.

Interior Temperature Measurement

The temperature maintained in a conditioned space is a primary determinant of energy usage. In most buildings, the temperature measured at a particular instant can vary significantly depending on the sensor location. For this study, we wish to measure reference temperatures that yield information on the pattern and comparative level of interior temperature.

A trade-off between representativeness and ease of measurement is necessary. Temperature sensors are to be installed so as to minimize inconvenience to occupants during installation, adverse aesthetic impacts, and damage to the buildings. Installation of temperature sensors in the center of conditioned zones would require lengthy cables and intrusion into occupied areas.

If the HVAC system employs a return air plenum, measurement of the duct temperature would be adequate. Where this is not possible, installation of a temperature probe in interior zones adjacent to the data logger can be considered so long as the zones are conditioned in a representative way and the probes are distant from sources of process heat or drafts.

Microclimate Measurement

The ELCAP project will install approximately ten microclimate stations on selected commercial sites. The station is to be installed on the roof or on a mast adjacent to the building in such a way as to provide true and unobstructed measurements of wind speed and direction, air temperature, and solar radiation. The equipment is to be calibrated against industry standards and maintained on a quarterly basis, at a minimum.

MEASUREMENT PLAN DEVELOPMENT PROCEDURES

This section describes our step-by-step approach to the development, documentation, and approval of measurement plans.

Step One: Complete Measurement Plan Worksheet

Complete the information on the worksheet and make a preliminary determination of the suitability of the building. Identify building zones, fossil fuels or steam use, and check off completion of measurement plan forms.

Step Two: Document Location and Purpose of Electrical Panels

Complete the panel and switchgear location document to include name, location, voltage, and relevant comments.

Step Three: Complete Switchgear and Panel Documentation Forms

Determine the connected loads on the various circuits and document on the appropriate forms.

Step Four: Classify Circuits According to End-Use

Identify the measurements required to separate out HVAC, lighting, and other energy use by completing the appropriate end-use check sheets and the sensor requirements form. Also, identify available proxy circuits for fossil fuel use, if applicable, on the channel formulation form.

Step Five: Make Sensor Assignments

Estimate the number of current transformers needed on the Sensor Requirements Form. Revise initial estimates as necessary for initial measurement plan, and document current transformers (CT) numbers on the Panel/Switchgear Documentation Forms.

Step Six: Complete Channel Formulation Form

Determine the formula that is used to calculate the necessary end-use consumption levels. Document these formulas on the Channel Formulation Form.

Step Seven: Submit Measurement Plan for Approval

Deliver the measurement plan worksheet, updated contact form, and draft measurement plan or building exception/rejection form for approval to PNL technical representative.

Step Eight: Install Equipment and Update Plan

Install equipment as outlined in the approved measurement plan following instructions in the installation handbook. Document any material deviations from the plan by making entries in red and providing a summary of the reasons for alterations for final submission to PNL.

Step Nine: Modify Installation (if required)

Evaluate updated measurement plans for final approval. If required, complete necessary modifications and submit modified instrumentation plan to PNL.

A sample set of forms is available from the authors.

INSTALLATION ACTIVITIES

The tasks necessary to install the metering equipment include mounting the field data acquisition system (FDAS), installing CTs in the panels, installing conduit for CT leads, mounting the inside temperature sensor, integrating the CTs with the FDAS, scaling the CT outputs, performing the communication checks, and at some sites, installing a meteorological station.

Mounting the FDAS

The FDAS is mounted on a wall at a location convenient to the panels or switch box to minimize the amount of conduit required. The leads for the CTs are 8 ft long, so if the FDAS is near the panels, conduit may not be required. In most buildings, however, the panels are distributed on the same floor or different floors, and conduit or multipair wire runs are required.

The FDAS is held in place by four bolts mounted in the existing wall surface. In some cases, the FDAS is first mounted on a plywood sheet that is attached to the wall. The FDAS weighs approximately 50 lb and is 18 x 24 in.

Installing CTs in the Panels

Current transformers will be installed within the electrical breaker panels if adequate room exists (see Figure 9-2). If adequate room does not exist, CTs will be mounted in a separate external enclosure. We expect external enclosures to be required only in older buildings. Installing the CTs requires the electrician to throw the breaker, remove the wire connected to the breaker, slip the CT on the

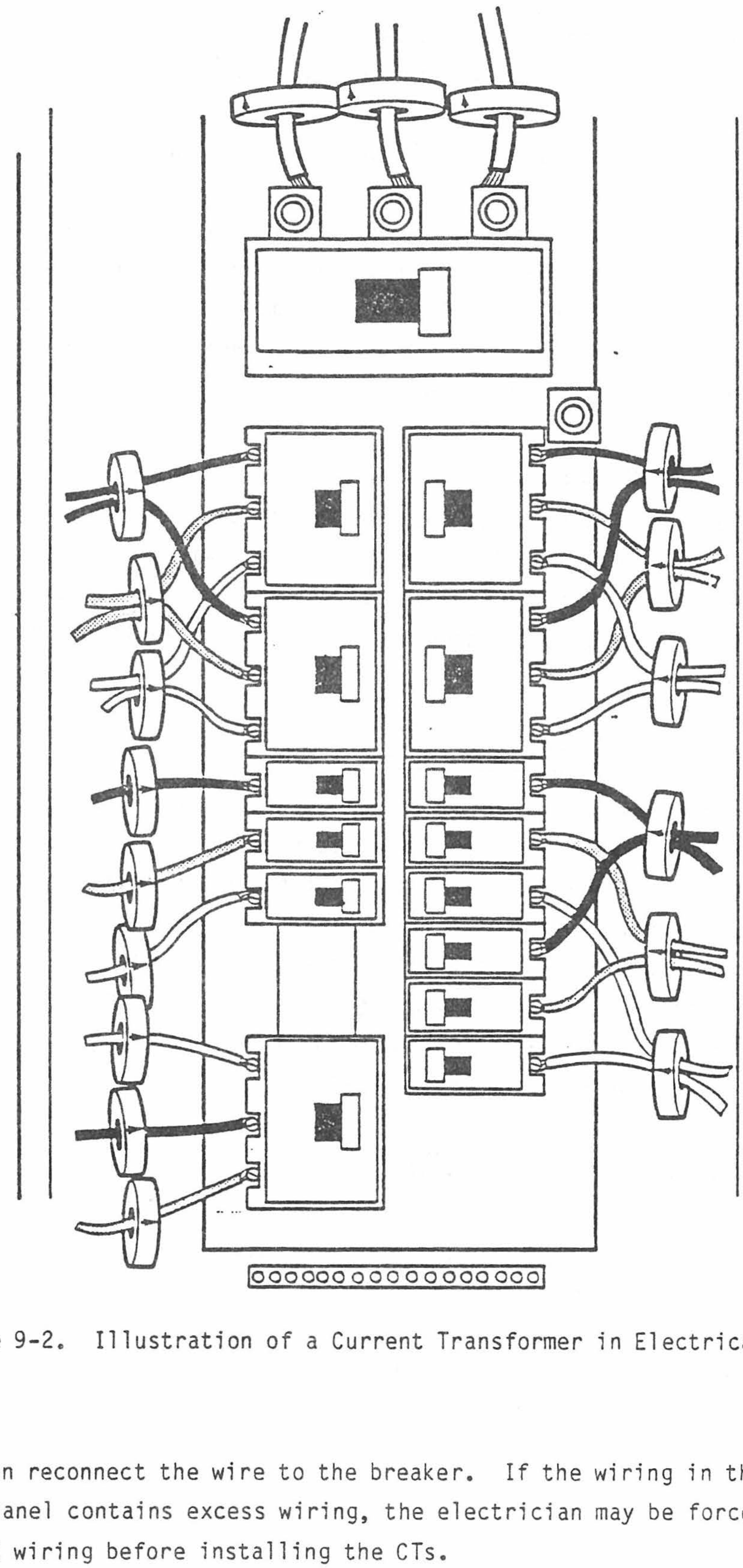

Figure 9-2. Illustration of a Current Transformer in Electrical Panel

wire, and then reconnect the wire to the breaker. If the wiring in the panel is not neat or the panel contains excess wiring, the electrician may be forced to clean up the panel and wiring before installing the CTs.

The incoming main service to the building is also metered to check the sum of the individual phases that are being metered. Because the incoming service may be of large amperage (>200 A) and be lower gauge wire, the effort required to break service to the building is generally time consuming and costly. Therefore, split-core CTs, especially developed for this program, are preferred for metering the end use of the service mains. The split-core CTs are two halves of a CT that are held together by a pressure-fitted clamp. They can be easily placed around a wire if ample room in the panel exists and the diameter of the wire is less than the effective inside diameter of the split-core CT. Smaller amperage split-core CTs were developed for circuits that cannot be turned off.

Installing Conduit for CT Leads

If the FDAS is located at some distance from the panel(s), multipair wire will be required to connect the CTs to the FDAS. This wire is generally placed in conduit to protect the wire from sharp objects or other construction activities in the building. The conduit is secured to the existing walls by anchors or other acceptable means.

Mounting the Inside Temperature Sensor

A single temperature sensor is installed in the normal activity area of the building. The temperature data are acquired to support modeling studies of the thermal performance of the building. Installing the temperature sensor requires that a four-conductor wire be run from the FDAS to the appropriate location. This is generally done by placing the wire between walls or in little-used areas and then bringing the wire to an existing light switch. By using a double-gang plate, the actual sensor is mounted in a thermostat cover on the unused portion of the plate. Figure 9-3 illustrates the installation of the sensor.

Integrating the CTs with the FDAS

After installing the FDAS and the CTs in the panel, mounting multipair wire and conduit, and installing the temperature sensor, the system can be integrated into a workable unit. The CTs are connected to watt-hour boards with barrier strips. Individual CTs are marked with numbers in the panel, and their leads are marked with the same number at a point near the connection to the watt-hour card. The number assigned to the CT is the FDAS channel number. The temperature sensor is connected directly to the FDAS at appropriately marked pin locations.

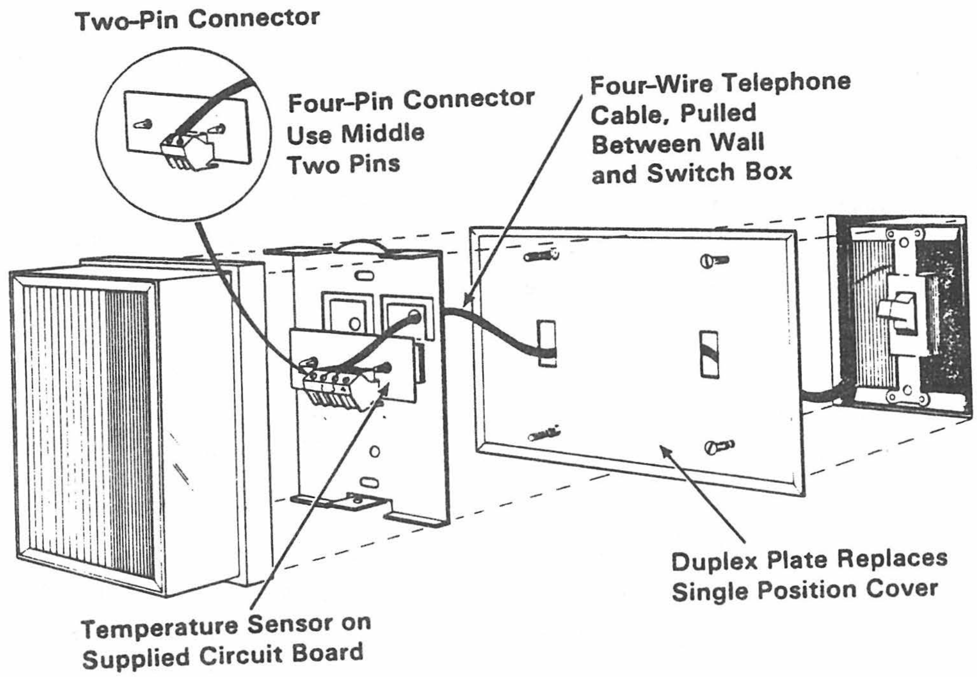

Figure 9-3. Illustration of the Indoor Temperature Sensor Assembly with Standard Light Switch Plate

The FDAS stores the acquired data in memory, and that information is sent through a telephone connection to a computer at PNL. This transfer requires the use of a modem to complete the computer link as well as the use of a telephone line. A dedicated telephone line is used to eliminate interference with normal telephone activities in the building. This line, which terminates at a jack near the FDAS, is connected to the modem in the FDAS using a short run of commercially available telephone wire.

Scaling the CT Outputs

The CTs used in the metering program are designed for use on circuits of 30, 100, and 400 A. To improve the resolution of the watt-hour meter output, each metering circuit is scaled to the value of breakers that are being metered. For example, if a 100-A CT is being used to meter breakers that are rated 60 A, the watt-hour meter output needs to be scaled down to some value near 60 A to maximize its resolution. This is accomplished by using scaling resistors on the watt-hour cards. Using a 100-kOhm resistor as the default choice that allows the watt-hour meter maximum resolution at its rated value, a 200-kOhm resistor would scale the circuit to 50% of its rated value. A 100-A CT would then appear to be a 50-A CT and provide the maximum resolution of its output. For the case noted above, a 133-kOhm resistor would be used to scale the 100-A CT by 66.67% or approximately 67 A. Each channel must be scaled to a value that is near the total amperage that is being metered.

Performing the Communication Checks

Before leaving the site, the installation contractor calls PNL for a communication check of the FDAS unit. This check is used to determine if the modem is operating correctly and obvious loads are being monitored.

Results of the pilot study indicated that some other checks were required to eliminate obvious installation errors. The expanded checkout procedure is described in the section on changes made as a result of the pilot study.

Installing a Meteorological Station

A meteorological station is installed at selected sites to provide climatic data for use in thermal performance modeling. The station consists of sensors to monitor wind speed and direction, ambient temperature, and solar radiation, and is attached to a portable mast mounted on the roof of the building.

Signal wires from the station are run to the FDAS via an existing vent in the building. The wires are connected to the prescribed pin locations on the main logger's printed circuit board. The level of skill required to complete installation of the station generally requires that this task be assigned to a technical specialist with experience with meteorological sensors.

RESULTS OF PILOT STUDY

Metering equipment was installed in 16 buildings in Seattle City Light's service area as part of a pilot study. The purpose of the pilot study was to check out measurement plan preparation and installation procedures, test the metering equipment to be used in the full-scale study, evaluate the skill of personnel involved in the various tasks, and determine how well the overall procedures apply to a variety of building types. Various problems related to using the measurement plans, performing the actual installations, and other aspects related to the installation process are described, along with changes made in the procedures and approach as result of the pilot study.

Problems Associated with Measurement Plans

After the measurement plan was completed and approved, it became the basis for installing the metering equipment. After the installation was completed, the metering equipment was inspected by PNL staff. The following types of problems were found with most of the measurement plans:

- wrong current phase identified
- CTs over- or underscaled
- end-use loads unmetered
- wrong or mixed aggregation of loads
- incomplete information regarding electrical distribution system or building characteristics.

A physical inspection of the installation revealed the following problems in most of the buildings:

- misoriented CTs
- misplaced CTs
- improper size of CT installed
- CT leads miswired to watt-hour board
- minor electrical code violations.

Other general problems included equipment that did not operate according to specification and evidence of failure of the installers to read and understand the documentation provided by PNL.

In spite of these problems, some program objectives were met. For example, the PNL project team gained a better appreciation of the amount of effort required during the various phases of the installation process. Also, the pilot study allowed us to test our procedures on a variety of contractors and building types, and provided valuable information to use in revising installation procedures for the full-scale study.

Contractor Cost

In the pilot study, each contractor was responsible for preparing measurement plans and installing metering equipment in two buildings. Before beginning these activities, a training session was held to review the procedures, visit an existing metering site, and answer any questions related to the entire process. During the first installation, PNL technical specialists were on hand to review how the contractors approached the installation activities, including their interaction with the tenant(s) and preparation of the measurement plan. Once the measurement plan was approved by the measurement plan coordinator, the installation proceeded. During this phase of the work, the PNL technical specialist worked with the contractor to provide training on the metering hardware and installation techniques. The contractor was solely responsible for completing installation in the second building. Contractors were required, however, to have the measurement plan reviewed and approved.

The average cost per building for the eight contractors that participated in the commercial pilot study was $3,538. The range of the average cost was $2,464 to $5,000, with a standard deviation of $831. These figures include the cost associated with the initial training session conducted by PNL.

CHANGES MADE AS RESULT OF PILOT STUDY

Based on the problems noted, it was apparent that several changes were needed. First, the procedures for preparing the measurement plan and installing the metering equipment have been expanded to provide a checklist for various task activities. Second, more illustrations have been placed in the procedures to show the configuration of the equipment and to identify various checkpoints in the FDAS. These checklists provide repetitive checks that allow some measure of contractor quality-control checking. Some additional procedures have also been generated. For example, if the measurement plan is altered by the installation team to overcome installation problems, such as changing the recommended CT size, an Installation Change Notice (ICN) form is completed.

A standard load test was developed to catch installation problems such as misoriented or misplaced CTs, improper scaling resistors, and CTs with reversed leads. This procedure requires the installation team to subject each CT to a known current. The CT output is then monitored via a communication link with a portable computer to determine if the same approximate current is observed. This information is typically sent over the dedicated telephone line to a portable computer at PNL, and provides the additional assurance that the communication link with the laboratory exists, and the system functions as planned.

The installation contractor now provides an initial review and cost estimate for generating a measurement plan and completing the installation for each building. During this initial visit, various obstacles to completing the installation or metering program are listed by the contractor for review by PNL staff. If these obstacles are deemed to be excessive or to markedly increase the cost of the installation effort, the building will be rejected.

Section 10

COMMERCIAL BUILDING RECRUITMENT FOR THE END-USE LOAD AND CONSERVATION ASSESSMENT PROGRAM

Richard P. Mazzucchi* and Scott N. Craig*

INTRODUCTION

Relations with building owners and tenants are crucial to the success of any monitoring project. This is particularly true when randomized sampling procedures are employed, wherein high participation rates are desirable to minimize possible bias. This paper describes the approach and procedures employed by the End-Use Load and Conservation Assessment Program (ELCAP) to secure and maintain access to monitoring sites in the commercial sector.

The ELCAP commercial sample in Seattle is targeted at 200 sites. Thirty of the sites are selected from a group of approximately 60 buildings constructed since 1981. The remaining 170 sites are apportioned to various building types based on an estimate of the share of the regional electrical load. Approximately 1,000 candidate sites for this sample were randomly drawn from some 12,000 tax assessor records maintained by the City of Seattle on commercial parcels.

The material presented in this paper is complemented by other papers appearing in this proceedings. The paper on installation activities describes the process by which the measurement plan is applied at a particular site with respect to the hardware configuration. Another paper on supporting data provides insight into the types of information collected to support verification and analysis of the field measurements.

RECRUITMENT APPROACH

The methods used to recruit participants for the ELCAP project were devised in response to the following programmatic considerations:

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*Pacific Northwest Laboratory, Richland, Washington.

- high participation rates (>70%) from a randomized list of sites
- no provision for nuisance payments
- data to be shared only after two years of data collection
- no promise of conservation assessment or analysis
- signed agreement granting access to building, data, and utility billing records.

These stringent criteria were established to limit sample bias, reduce project costs, and legally authorize project activities.

The primary challenge is to convince the candidate that the long-term benefits of participation outweigh the short-term inconvenience. Once the candidates are assured that all project costs and liabilities are borne by the sponsor, they must be educated with respect to the value of the information the project will compile and the requirements that participation will impose.

A multistage recruitment process is used to carefully approach the candidate and secure participation. The major stages are as follows

1. Assemble available site information.
2. Make initial contact telephone call.
3. Deliver introductory letter and brochure.
4. Make follow-up telephone call.
5. Conduct onsite briefing.
6. Negotiate access agreement.

The first step involves gathering all information on the candidate site that is readily available. For this project, this includes data from the tax assessor office, fire rating bureau, telephone directories, and a 'drive-by audit' conducted to verify the accuracy of the information from secondary sources. A sample drive-by audit form is provided in the Appendix A.

In most cases the owner and tenants of the candidate sites are known, and the purpose of the initial contact telephone call is to verify the name and address of the individual authorized to grant access to the site. Where the above information is incomplete, it is necessary for the recruiter to acquire it during this contact in order to proceed. This call is very brief and discussion of the project in any detail is discouraged. The candidate is informed that materials describing the project will be sent and that we will discuss the opportunity further after the material is reviewed.

Two versions of the introductory letter have been developed; one is oriented toward large buildings or corporations, the other toward small 'ma and pa'-type businesses. The first version appeals to business executives and uses rather sophisticated language, while the second is simple and direct. Adverse reactions to the first version by small businesses led to the development of the second version. Copies of both letters as well as the brochure attached are included in Appendix A.

Approximately one week after mailing the introductory material, a telephone call is made to the recipient to answer any general questions and schedule an onsite briefing. If the candidate refuses to grant a briefing, an inquiry is made as to the reasons why. Usually, this results in clearing up misunderstandings and eventual debriefing. A review of the reasons for rejection is presented later in this paper.

Just before the scheduled briefing, the recruiter calls to confirm the appointment and remind the candidate of the project. The briefing, usually conducted at the owner's office, is composed of two portions. The first portion lasts about 15 minutes and makes use of a notebook to describe the project goals, major activities, and the benefits of participation. This notebook contains photographs of an actual installation, samples of the data products, and listing of the project requirements. During the briefing, questions are encouraged and answered. A copy of the access agreement shown in Appendix A is then presented.

The second portion of the briefing is a line-by-line review of the access agreement and is conducted only as appropriate. In many cases the candidate indicates that lawyers or business partners must review the agreement before signature. The candidate is encouraged to modify the agreement as needed, rather than reject it out of hand.

If the agreement is not received in a reasonable period (the duration depends on the number and complexity of approvals) the recruiter will make a telephone inquiry. In a few cases, a written inquiry may be required to contact the candidate. If the access agreement is modified, a concurrence review is made by project staff and negotiations to reach agreement on specific terms proceed.

A computerized tracking system is used to document recruitment progress at particular sites as well as overall. This system provides a record of the dates and durations of the stages described above, detailed information gathered during the recruitment, and a status of recruitment progress. Samples of the site-tracking log, recruitment calendar, and status report are included in Appendix B.

RECRUITMENT EXPERIENCES

This discussion of the results of the ELCAP recruitment effort is based on experience through February 22, 1985. Only the initial version of the contact letter was used during this period, so experience with the second version is not presented here. We expect that the revised materials oriented toward small businesses will significantly improve participation rates in this area.

To date, 144 sites have been visited. A total of 79 access agreements have been signed, 18 sites installed, and 43 sites rejected. The remaining sites are considered probable participants; however, signed agreements have not been received. The overall participation rate ranges from 55% to 69% depending on the number of probable sites that actually sign up. This is below our target of 70%, and precipitated a review of recruitment procedures.

The status of sites as of February 22, 1985, is shown in Figure 10-1. The number of sites targeted, signed, probable, and rejected in each of four building categories is presented. The graphic clearly shows the major problem area to be small buildings, where 21 sites have been recruited, but 26 have been rejected. Participation rates in the new (post 1981 construction) and large categories exceed our expectations at 84% and 73%, respectively.

A review of the point of rejection reveals that about 15% of the sites decline at the initial call, 60% at the follow-up call, and the remaining 15% following the on-site briefing. Hence, our attention focused on improving the introductory material that describes the project. The consensus of recruiters is that the first version of the letter does not favorably present the project in the eyes of small business candidates.

The reasons given for rejection are reported on an exception/rejection form, a sample of which is included in Appendix B. Our review reveals that the major reasons for rejection are the desire for privacy; the benefit being perceived as limited, usually because of low electric usage; or predisposition not to participate in utility programs.

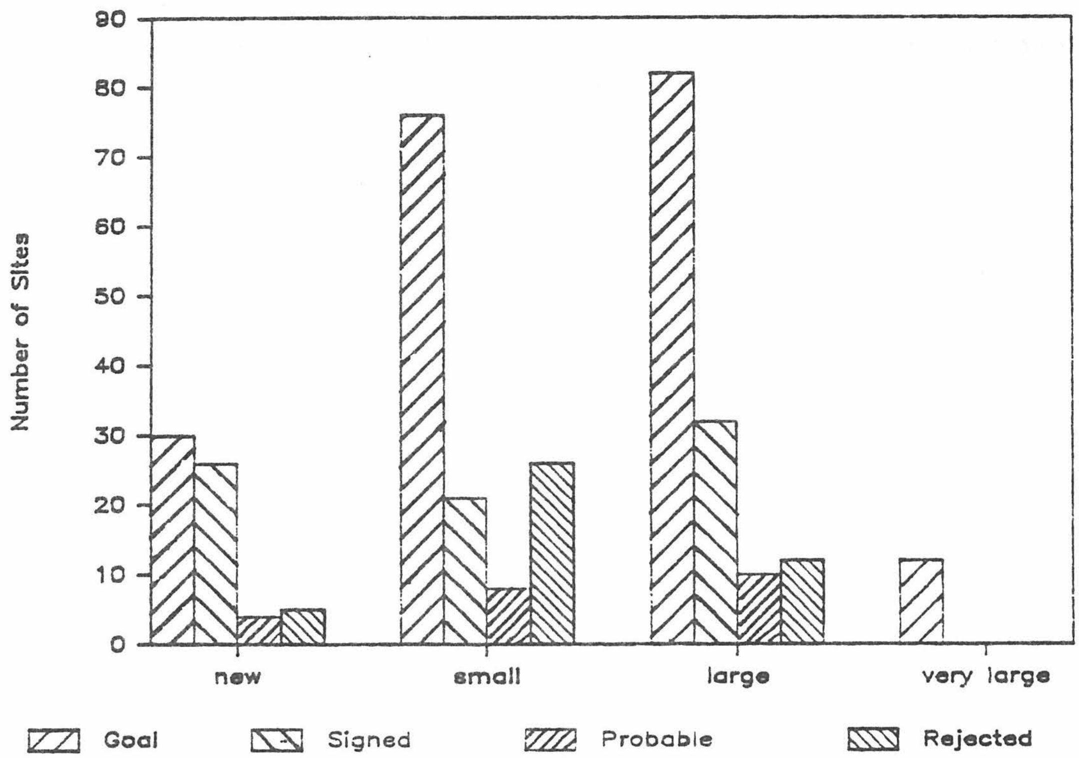


Figure 10-1. Status of Sites in the Four Building Categories as of February 22, 1985.

The fact that participants must wait at least two years for any potential benefits to materialize is particularly disconcerting to small businesses, which have a relatively short planning horizon.

A common misperception is that we are trying to sell something, probably a conditioned response to energy conservation product manufacturers who have begun marketing in the service area. This can be cleared up only if the candidate is willing to listen, which occasionally is not the case. Another issue, which has yet to be adequately addressed, is cultural/language barriers. Certain ethnic groups seem predisposed not to participate in projects of this type to protect their collective privacy or avoid interaction with 'outsiders'. This may be overcome by using recruiters who speak foreign languages or share similar ethnic origins.

In summary, the recruitment activity has revealed a number of issues that will most likely affect other studies of this type, as well as other programs aimed at influencing energy use. We believe that overall participation rates for commercial buildings can be brought to the target level with careful attention to the perspective and disposition of small business owners. However, to secure targeted participation rates for small businesses, early data sharing, energy conservation recommendations, or nuisance payments may be required.

APPENDIX A

ELCAP RECRUITMENT MATERIAL

Sample Drive-by Audit Form

ELCAP COMMERCIAL BUILDING DRIVE-BY SURVEY CASE # [DBY385]

A. BUILDING IDENTIFICATION

SITE ID [WAR506]06
TAX ACCOUNT # [352304-9110]

1. BUILDING NAME (LARGEST STRUCTURE) [ ]

2. FIRM NAME LARGEST TENANT [SUPPLY CTR]

3 FIRM NAME 2ND LARGEST TENANT [BIKE SUPPLY]

4. FIRM NAME 3RD LARGEST TENANT [PLASTICS, INC.]

5. FIRM NAME 4TH LARGEST TENANT [CHINA]

6. PRINCIPAL ADDRESS [105 LAND DRIVE]

7. SECOND ADDRESS [109 LAND DRIVE]

8. THIRD ADDRESS [113 LAND DRIVE]

9. FOURTH ADDRESS [121 UPLAND DRIVE]

10 NUMBER OF STRUCTURES ON PARCEL [4]

11. NUMBER OF TENANTS IN BUILDINGS ON THE PARCEL [20]

12. GENERAL CONDITIONS OF THE BUILDING[BLDG MEASURED ONE OF AT LEAST]

[FOUR IN BOEING-OWNED BUSINESS PARK/OFFICES & WAREHOUSE]

B. BUILDING ACTIVITIES -- LARGEST STRUCTURE

	SIC	% OF GROSS FLOOR AREA
1. BUILDING USE ONE	[4226]	[15]
DESCRIBE BRIEFLY	[BUILDING MATERIALS SUPPLY WAREHOUSE]	
2. BUILDING USE TWO	[4226]	[15]
DESCRIBE BRIEFLY	[WAREHOUSING FOR BICYCLE PARTS]	
3. BUILDING USE THREE	[4226]	[15]
DESCRIBE BRIEFLY	[PLASTICS COMPANY]	
4. BUILDING USE FOUR	[4226]	[15]
DESCRIBE BRIEFLY	[CHINA WHOLESALER/WAREHOUSER]	
5. % FLOOR AREA VACANT	[20]	

C. BUILDING ACTIVITIES -- OTHER BUILDINGS

PRINCIPAL USE	SIC	TOTAL BUILDING FLOOR AREA
1. BUILDING # 2	[1]	[100000]
DESCRIBE BRIEFLY	[OFFICES/WAREHOUSES]	
2. BUILDING # 3	[1]	[100000]
DESCRIBE BRIEFLY	[OFFICES/WAREHOUSES]	
3. BUILDING # 4	[1]	[100000]
DESCRIBE BRIEFLY	[OFFICES/WAREHOUSES]	

D. BUILDING PHYSICAL CHARACTERISTICS -- LARGEST STRUCTURE

1. APPROXIMATE GROSS FLOOR AREA (INCLUDING PARKING INTEGRAL TO STRUCTURE) [100000]

2. NUMBER OF FLOORS (ABOVE MIN. GRADE) [1]

3. NUMBER OF FLOORS OF PARKING (INTEGRAL TO STRUCTURE) [0]

3. APPROXIMATE HEIGHT (ABOVE MIN. GRADE) [20]

4. NUMBER OF SHARED WALLS [0]

5. % OF WALL AREA SHARED [0]

6. PRINCIPAL TYPE OF CONSTRUCTION FOR LARGEST STRUCTURE

(CODING: WOOD = 1
MASONARY = 2
GLASS/STEEL = 3
STUCCO = 4)

[2]

7. APPROXIMATE YEAR BUILT (NEAREST DECADE) [1970]

8. HAVE THERE BEEN MAJOR ADDITIONS (CODING: YES = 1 NO = 2)

[2]

E. FUEL CHARACTERISTICS -- ALL STRUCTURES

1. NUMBER OF VISIBLE ELECTRICAL MASTS [0]

2. NUMBER OF GAS METERS [7]

Sample Initial Letters and Brochure

SAMPLE INITIAL LETTER

Dear businessperson,

Battelle is studying energy usage in commercial buildings throughout the Northwest in a program sponsored by the United States Department of Energy. The purpose of the program is not only to understand when, where, and why energy is being used in commercial structures, but also to save you money.

In order to determine which energy conservation techniques are best for a specific type of building, it is necessary to study individual buildings. Your building has been selected as a possible participant in this study.

This study will provide you with valuable information regarding your energy consumption absolutely free of charge. You will receive a written report which includes the following:

* a characteristics audit of your building
* a listing of the energy consuming devices in your building
* a comparison of energy use in your building with energy use in similar buildings

This report will provide you with a thorough understanding of how you use energy in your building. It will also alert you if you or your employees have developed energy wasting habits. Enclosed is an example of how the information you will receive can save you money.

I will be calling you on (specific date) to schedule a brief meeting to tell you more about this unique opportunity. Thank you for your interest.

Sincerely,

Battelle's Pacific Northwest Laboratory (PNL) is conducting a scientific study of building energy use entitled the "End Use Load and Conservations Assessment Program" for the Bonneville Power Administration (BPA). The primary objective is to determine when, where, and why energy is used in buildings in the Pacific Northwest, and to relate this information to building design and operating conditions. The project results will reveal building energy consumption patterns and lead to an improved understanding of energy conservation potentials and utility power requirements.

Your building at STREET ADDRESS in Seattle has been selected as a candidate for participation in this study. If the building owners and tenants are willing, Battelle may conduct a characteristics audit of the building and install a customized data acquisition system. This computerized system will sense energy flows and building operating conditions and automatically deliver data to our laboratory over a dedicated telephone line. After data is compiled for two years, reports will be provided which present summaries of the metered data and the results of energy audits and analytical efforts. This report can provide valuable insights into energy consumption within your building.

Our equipment is housed in a box approximately the size of a circuit breaker panel, and is installed near the existing electrical service panels. Once the equipment is installed, there will be no scheduled visits to the building. The total cost of this project will be paid for by BPA.

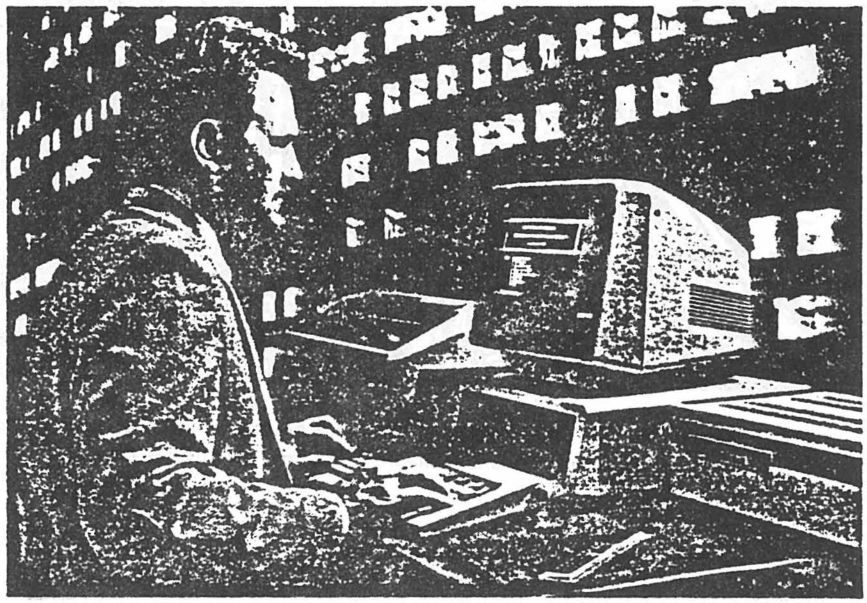
In order to participate in the study, the building owner or an authorized representative must sign an agreement with Battelle. This allows Battelle to gather the necessary data.

I will call you on (specific date) to schedule a brief meeting to further describe this project and answer any questions. I have enclosed a description of Battelle and an information sheet explaining the value of the program to your business. Thank you for your interest.

Sincerely,

Energy Analyses of Buildings

Conservation measures for buildings offer significant potential energy savings. However, to best realize these benefits, decision makers need to know which conservation measures offer the greatest return on investment. Researchers at Battelle's Pacific Northwest Laboratories can identify the most feasible conservation options and estimate their cost effectiveness. This research has proven valuable in regional energy forecasting and can further serve building designers, utilities, equipment manufacturers, and various energy users.



A Battelle-developed data-acquisition system gathers information on energy consumption in buildings and relays the information to researchers who use it to evaluate strategies for energy conservation and utility load management.

Meeting Energy Demands

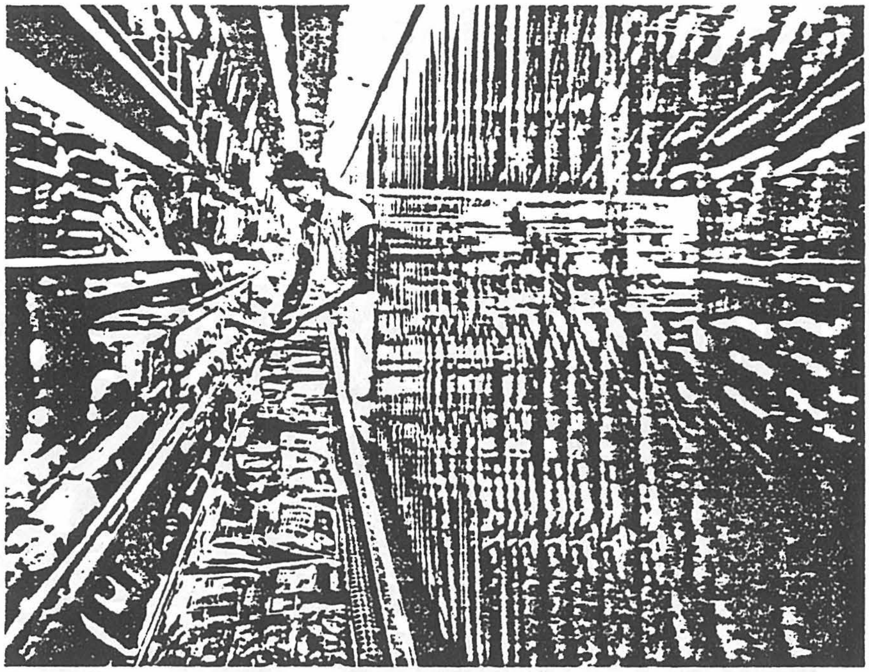
One third of the energy consumed in the United States is used in buildings for lighting, heating, cooling, and ventilation as well as for vertical transportation, appliances and specialized processes. To help clients meet these energy demands as efficiently and economically as possible, Battelle-Northwest conducts building-specific energy analyses.

Applying complex simulation methods, our researchers estimate the energy performance of buildings before and after the implementation of proposed energy conservation measures. Field data are used to verify the estimates. The studies reveal how energy is used in buildings and how designs, occupancy and operation affect levels of use. From this information we identify energy-saving measures and assess strategies for energy conservation and utility load management.

Gathering Field Data

Because of the lack of high-quality data relating to building energy use, researchers have had to rely on theoretical simulation methods. Now, however, Battelle-Northwest is assembling available field data plus new information acquired through customized metering activities. This comprehensive data base makes it possible to predict the effectiveness of proposed energy conservation actions more confidently, thereby reducing the risk associated with major capital investments in energy-saving measures.

Our staff has developed advanced research methods for data collection. A low-cost data-logging instrument, for example, can be installed in near or distant buildings to gather and relay information on energy consumption according to end-use and time of day. Automated processing techniques have also been developed to accommodate data from various sources. Selecting from these and other methods, we can apply the best possible techniques for acquiring the needed data.



A vinyl curtain that reduces refrigeration and space heating needs in grocery stores is one of many energy-saving options available to commercial businesses.

Applying these instruments and data analysis techniques, we can help solve a wide range of building energy use problems. Equipment manufacturers, for example, can verify the efficiency of their products through a metering study. To help building owners and operators identify money-saving opportunities, we can investigate energy use patterns and conservation strategies for particular buildings. We can also help utilities improve load forecasts and develop programs designed to acquire energy conservation resources.

Applied Expertise

Battelle-Northwest researchers have acquired extensive experience in building energy analyses through investigations performed for government agencies, utilities and building industry organizations. A landmark study, for example, was conducted for a regional power planning organization to establish resource acquisition priorities. Using the results, the organization has devised an innovative power-forecasting plan that considers energy conservation along with supply options to meet future energy demands.

Our research provides technical support for the development of improved building standards and conservation practices. Through a series of articles in trade magazines, we share findings with the building design community so the information can be directly applied to construction practices. In other efforts, we have produced building design manuals for particular building types and climates.

Ready Assistance

Motivated by the potential cost benefits of energy conservation in buildings, private firms and public agencies are looking closely at building design and operations to determine feasible measures for energy savings. Utilities and legislators are evaluating building conservation as an energy resource and seeking reliable information to aid planning and program development. Equipment manufacturers and entrepreneurs are investigating marketing opportunities for energy conservation products.

We offer responsive, cost-effective technical expertise to support these efforts. The research, which is available to businesses, utilities and governmental agencies on a contract basis, can be funded by a single organization or a group of firms sharing the costs and benefits. Studies can range from simple data summaries to total research programs.

For further information on building energy analyses, contact:

Richard P. Mazzucchi, Manager
Building Energy Analyses
(509) 376-4362

L. D. (Don) Williams, Manager
Energy Systems Department
(509) 376-4732

Battelle/Pacific Northwest Division
P.O. Box 999
Richland, Washington 99352

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Pacific Northwest Division

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Access Agreement

COOPERATIVE AGREEMENT
END-USE LOAD AND CONSERVATION ASSESSMENT PROGRAM
(COMMERCIAL)

THIS COOPERATIVE AGREEMENT is made between the PACIFIC NORTHWEST LABORATORIES, BATTELLE MEMORIAL INSTITUTE, a corporation organized and existing under the laws of the State of Ohio, with principal offices in the City of Columbus, Ohio (Battelle), and ______________________________, (a corporation, sole proprietorship, partnership, individual, joint venture) located in the City of ______________________________ (Permitor).

The Permitor is the owner or owner representative of the ____________________ ____________________ building at ____________________________________ (Building).

Battelle in the performance of its Prime Contract DE-AC06-76RLO 1830 with the United States Department of Energy (DOE) is performing a research project to assess the end-use of electrical power in commercial and residential buildings in the Bonneville Power Administration (BPA) service region. The results will be used to assess the accuracy of estimates in conservation potential and to establish a data base of electrical end-use.

A. The Permitor hereby agrees to permit Battelle, its authorized representatives, and subcontractors to:

   1. collect data about price and usage (energy-use) from the Permitor's energy suppliers

   2. perform energy audits (audits)

   3. gather energy consumption and determinant data through computerized monitors attached to the Building's energy system (metering) which may require the temporary interruption of electrical service.

B. Project activities are subject to the following conditions:

   1. Activities shall commence on or after ____________, ________.

   2. Battelle responsibilities shall be transferrable to the BPA at any time.

   3. The Permitor shall not bear any costs of the installation, maintenance, or removal of metering equipment.

   4. Battelle will comply with Federal, State and local safety; employer liability; workers' compensation; and building and electrical codes, laws, rules and regulations.

   5. Project equipment installed by Battelle will be and remain the responsibility of Battelle until transfer (assignment) to the BPA. The Permitor has no liability or responsibility for installed equipment.

6. The Permitor shall provide a designated contact with whom Battelle can coordinate project activities in the Building, and any interaction with the Building's tenants affected by the project.

7. The Permitor agrees not to disturb installed equipment in any way, unless authorized by Battelle or as may become necessary for safety.

8. The Permitor agrees to coordinate with Battelle any changes in maintenance practices or physical alterations that could affect energy usage in the Building for the term of this Agreement.

9. Battelle will not publicize the Permitor's participation in the project. All data gathered becomes the property of DOE.

10. Permitor shall not use Battelle's name or identifying characteristics for advertising, sales promotion or other publicity purposes.

C. Battelle shall indemnify and save harmless the Permitor, its officers and employees against any and all claims, attorney's fees and court costs, for injury (including death) or damage to Permitor's property caused by the negligence or willful misconduct of Battelle's employees or subcontractors in designing, installing, repairing, checking, or using the metering equipment attached to the Permitor's energy system. The foregoing indemnity shall be limited in amount to the payments made or proceeds received by Battelle from the Continental Insurance Company under Policy No. L1311230 and Interstate Fire and Casualty Company under Policy No. 55-C2044267.

D. In consideration for the cooperation herein the Permitor shall be provided a summary report of the energy-use, audit, and metering results concerning its Building at the conclusion of this portion of the project.

E. Either party may terminate this Agreement by providing ninety (90) days' written advance notice to the other party.

Each signer of this Agreement has the authority to execute and bind the party involved and warrants that there are no other agreements, express or implied, which are not contained in this Cooperative Agreement or incorporated specifically by reference.

BATTELLE MEMORIAL INSTITUTE
PACIFIC NORTHWEST LABORATORIES

By ______________________________
Dean H. Glazier
Title Subcontract Specialist

Date ______________________________

Firm ______________________________

Signed ______________________________

Name ______________________________
(Please print)

Title ______________________________

Date ______________________________

0200A

COOPERATIVE AGREEMENT
END-USE LOAD AND CONSERVATION ASSESSMENT PROGRAM
(COMMERCIAL TENANT AGREEMENT)
BUILDING ADDRESS ____________________________

This attachment to the access agreement signed by the building owner is provided to identify and certify the tenants' compliance with the access agreement provisions. The tenant(s) identified below are participants in the End-Use Load and Conservation Assessment Program. Each participant has reviewed the attached access agreement for the building and will comply with its provisions. In recognition of this, Battelle will honor its responsibilities under the agreement with respect to each tenant.

	Tenant Name and Location	Authorized Signator	Signature	Date
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

APPENDIX B

ELCAP RECRUITMENT TRACKING MATERIAL

Sample Tracking Log

Old.WAR111
LG Warehouse

TRACKING LOG
ELCAP COMMERCIAL BUILDING SAMPLE
PART 1

****
INITIAL SITE DATA
****

Drv-by #: DBY000

Site ID . WAR000   Tax Account #. 111111-111

Building Name :

Building Address . 999 Any Street, City

Taxpayer Name . John Doe

Taxpayer Address : 999 Any Street, City

Taxpayer Phone # : 222-2222

Remarks . Info in book out of date. New owner, new tenant

****
TENANTS
****

Tenant #1: Warehouse Supply Co   Phone # . 222-2222

Contact : John Doe

Tenant #2. Freight Consolidators   Phone # .

Contact : John Doe (Warehouse Supply)

Tenant #3:   Phone # .

Contact :

Tenant #4:   Phone # .

Contact :

Remarks : Tenant # 2 will be moving in September

****
DIRECTORY
****

CONTACT #1

Name : John Doe

Title : Owner

Company Name : Warehouse Supply

Address : 999 Any Street, City

Phone # Work : 222-2222 Phone # Home

Remarks : Send Info

CONTACT #2

Name :

Title :

Company Name :

Address :

Phone # Work : Phone # Home

Remarks :

CONTACT #3

Name :

Title :

Company Name :

Address :

Phone # Work : Phone # Home

Remarks :

****

DATES

****

INITIAL CALL

Date contact process started 1/17/85

Date that person with authority to sign access agreement identified 1/17/85

Date initial contact letter sent 1/18/85

To whom : John Doe

FOLLOW-UP CALL

Date recipient of initial contact letter reached 1/24/85

Was the initial contact letter received? YES

If NO, date the letter was sent again

Initial contact letter sent to wrong person? NO

Remarks : * Interested

BRIEFING

Date of briefing 12/5/85 Time 12:00 pm

Appointment location : Warehouse Supply

Appointment with : John Doe

Remarks (Questions & Answers) :

****
BRIEFING
****

Post briefing notes :

* Two tenants: 1) Warehouse Supply
  2) Freight Consolidators

* Each tenant occupies 50 % of building

* Warehouse area is not heated

* 1 meter for whole building

* 2 subpanels, one for each tenant

* John Doe thinks it would be easy to run conduit from one subpanel to the other

* No building plans

* Warehouse Supply has a computer - can be turned off with prior notification

* Building area 19,650 sq. ft.

* John Doe will be the contact for the tenant. DO NOT contact the tenant directly.

Access agreement signed at briefing? YES
Remarks:

If NO, date access agreement signed
:

Signed by : John Doe

Date signed access agreement received @ HARC
:2/5/85

****
INFO NEEDED BY RICHLAND
****

Site ID # :WAR000:   Tax Account # :111111-1111 :

Amendments made by owner? NO   # of amendments

Remarks concerning amendments:

Contact for negotiating amendments :

Send executed agreement and installation notification letter to
:John Doe

SPECIAL INSTRUCTIONS:

Date tracking log and access agreement sent to BATTELLE, RICHLAND
[illegible]

****
TRACKING SHEET FOR RICHLAND
****

Site ID # :WAR000 : Tax Account # 111111-1111 .

Date signed access agreement with final amendments received in Richland

Date BATTELLE, RICHLAND executes access agreement

Date executed access agreement and installation notice sent to owner/authorized representative

****
CONTRACTOR INFORMATION
****

Name of installation contractor:

Date that authorization to proceed with measurement plans and installation for this site's group of buildings was sent to contractor

Anticipated completion date for this site's group of buildings

Date final access agreement, copies of installation notice and copy of Richland's tracking sheet received at HARC

****
INSTALLATION CONTRACTOR INFORMATION
****

Site ID # :WAR000   Tax Account # .111111-1111

INSTALLATION CONTACTS

Name :John Doe

Title :Owner

Company Name :Warehouse Supply Co

Address :999 Any Street, City

Phone :222-2222

Name :

Title :

Company Name :

Address :

Phone :

SPECIAL INSTRUCTIONS FOR INSTALLATION :

Warehouse Supply (and possibly the other tenant) has a computer
Do not interrupt power without prior notification.

WHO TO CONTACT TO GET BUILDING PLANS

Name :

Title : NO BUILDING PLANS AVAILABLE

Company Name :

Address :

Phone :

SPECIAL INSTRUCTIONS FOR GETTING BUILDING PLANS .

****
BUILDING REJECTED
****

Date of rejection :

Reason:

****
PRE-BRIEFING CONTACT - TENANT
****

Tenant Name.

Was the tentant contacted by telephone before the briefing?

Was a letter sent to the tenant?   If yes, when? . / / :
To whom?

****
BRIEFING APPOINTMENT - TENANT
****

Date of briefing : / / .   Time .

Appointment location : ^C

Appointment with : ^C

****
BRIEFING - TENANT
****

Post briefing notes : ^C

Access agreement signed at briefing? ^C
Remarks: ^C

If NO, date access agreement signed
: / / :

Signed by : ^C

Date signed access agreement received @ HARC
: / / :

Recruitment Calendar

:LDING TYPE		SITE NAME	SITE ID	CALL (INITIAL)	LETTER SENT	CALL (FOLLOW-UP)	BRIEFING	AGREEMENT SIGNED BY OWNER	AGREEMENT SIGNED BY TENANT	AGREEMENT SENT TO RICHLAND
Warehouse	Date		WAR302	02-Oct	15-Oct	22-Oct	25-Oct	07-Nov	no	04-Jan
(new) s	Days Since Start			0	13	20	23	36	tenant	94
	Date		WAR301	02-Oct	05-Oct	16-Oct	24-Oct	24-Oct	no	04-Jan
s	Days Since Start			0	3	14	22	22	tenant	94
	Date		WAR303	02-Oct	05-Oct	15-Oct	17-Oct	27-Nov	no	04-Jan
s	Days Since Start			0	3	13	15	56	tenant	94
	Date			02-Oct	05-Oct	12-Oct	no		no	
e	Days Since Start			0	3	10	briefing		tenant	Exception
	Date			02-Oct	05-Oct	REJECT				
r	Days Since Start			0	3					
	Date			26-Nov	28-Nov	13-Dec				
e	Days Since Start			0	2	17		Exception		
	Date		WAR401	03-Jan	07-Jan	16-Jan	22-Jan	19-Feb	No sig.	22-Feb
s	Days Since Start			0	4	13	19	47	needed	50
	Date		WAR304	03-Jan	10-Jan	14-Jan	15-Jan	15-Jan	NO	18-Jan
s	Days Since Start			0	7	11	12	12	TENANT	15
Warehouse	Date		WAR401P	PILOT						
Old-small) s	Days Since Start			RMazzucchi		RECRUITED				
PILOT	Date		WAR402P	PILOT						
s	Days Since Start			RMazzucchi		RECRUITED				
	Date			09-Nov	13-Nov	REJECT				
r	Days Since Start			0	4					
	Date		WAR001	09-Nov	13-Nov	19-Nov	29-Nov	05-Dec	no	04-Jan
s	Days Since Start			0	4	10	20	26	tenant	56
	Date			09-Nov	13-Nov	19-Nov	Call back			
	Days Since Start			0	4	10	in March			
	Date			14-Nov	20-Nov	28-Nov	REJECT			
r	Days Since Start			0	6	14				
	Date		WAR003	14-Nov	28-Nov	07-Dec	19-Dec	26-Dec		
s	Days Since Start			0	14	23	35	42		
	Date			30-Nov	10-Dec	15-Dec	EXCEPTION - Manufacturing			
e	Days Since Start			0	10	15				
	Date		WAR002	30-Nov	10-Dec	07-Jan	11-Jan	11-Jan	No	18-Jan
s	Days Since Start			0	10	38	42	42	tenant	49
Warehouse	Date			29-Nov	29-Nov	04-Jan				

Status Report

23-Feb-85

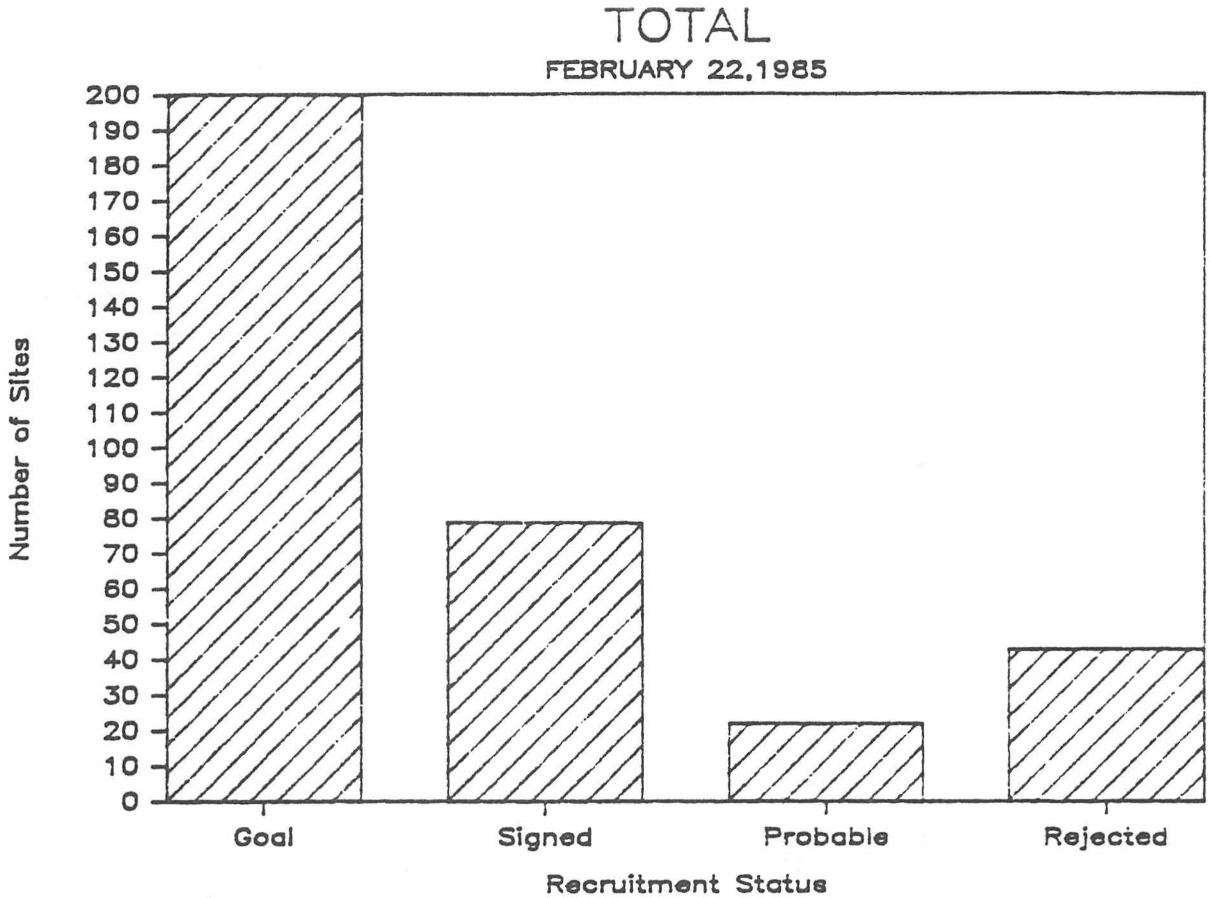
BUILDING TYPE	PRE 1981 TARGET	PRE 1981 SITES VISITED	PRE 1981 AA SIGNED	PRE 1981 SITES INSTALLED	PRE 1981 SITES VERIFIED	POST 1981 TARGET	POST 1981 SITES VISITED	POST 1981 AA SIGNED	POST 1981 SITES INSTALLED	POST 1981 SITES VERIFIED
Warehouse	19	20	13	2		5	7	5		
Dry Good	36	27	11	2		5	6	5	1	
Grocery	20	19	6	2		5	4	3	1	
Hotel	5	2	2	2			0			
Restaurant	18	15	3			5	7	4	2	
School	13	1	1	1			0			
Health	7	0	0				0			
University	7	0	0				0			
Office	34	22	14			10	11	9	1	
Other	11	3	3	3			0			
TOTAL	170	109	53	12		30	35	26	5	

Building Classification	Goal	AA Signed	Sites Probable	Rejected	Total Candidates	Candidate Sites Remaining
	Number of Sites					
WAREHOUSE						
new	5	5	1	1	14	8
small	4	5	0	2	15	8
large	13	8	2	3	22	11
very large	2	0	0	0	3	3
DRY GOOD RETAIL						
new	5	5	0	1	13	7
small	21	7	4	6	48	35
large	13	4	2	4	13	5
very large	2	0	0	0	1	1
GROCERY						
new	5	3	0	1	4	0
small	7	0	1	7	18	11
large	13	6	4	1	23	16
very large	0	0	0	0	0	0
HOTEL/MOTEL						
new	0	0	0	0	0	0
small	2	1	0	0	14	13
large	2	1	0	0	9	8
very large	1	0	0	0	8	8
RESTAURANT						
new	5	4	1	2	9	3
small	9	2	2	6	23	15
large	9	1	1	3	14	10
very large	0	0	0	0	0	0
SCHOOL						
new	0	0	0	0	0	0
small	8	1	0	0	21	20
large	3	0	0	0	5	5
very large	2	0	0	0	5	5
HEALTH SERVICES						
new	0	0	0	0	0	0
small	3	0	0	0	14	14
large	3	0	0	0	4	4
very large	1	0	0	0	11	11
UNIVERSITY						
new	0	0	0	0	0	0
small	5	0	0	0	13	13
large	2	0	0	0	3	3
very large	0	0	0	0	3	3

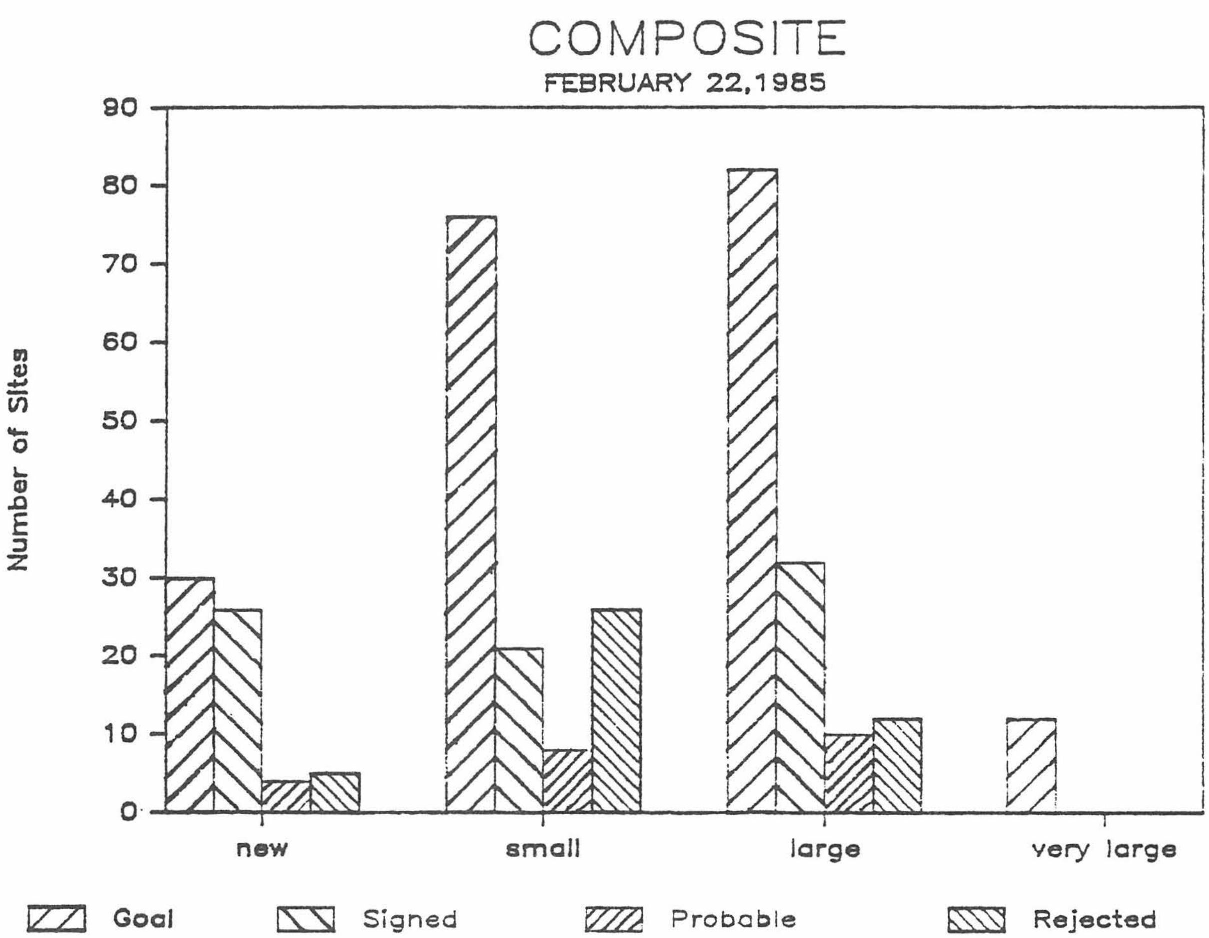
22-Feb-85 STATUS

Building Classification	Goal	AA Signed	Sites Probable	Rejected	Total Candidates	Candidate Sites Remaining
			Number of Sites			
OFFICE						
new	10	9	2	0	33	24
small	13	4	1	5	26	17
large	17	10	1	1	23	12
very large	4	0	0	0	13	13
OTHER						
new	0	0	0	0	0	0
small	4	1	0	0	14	13
large	7	2	0	0	24	22
very large	0	0	0	0	1	1
COMPOSITE						
new	30	26	4	5	73	42
small	76	21	8	26	206	159
large	82	32	10	12	140	96
very large	12	0	0	0	45	45
TOTAL	200	79	22	43	464	342

.4$



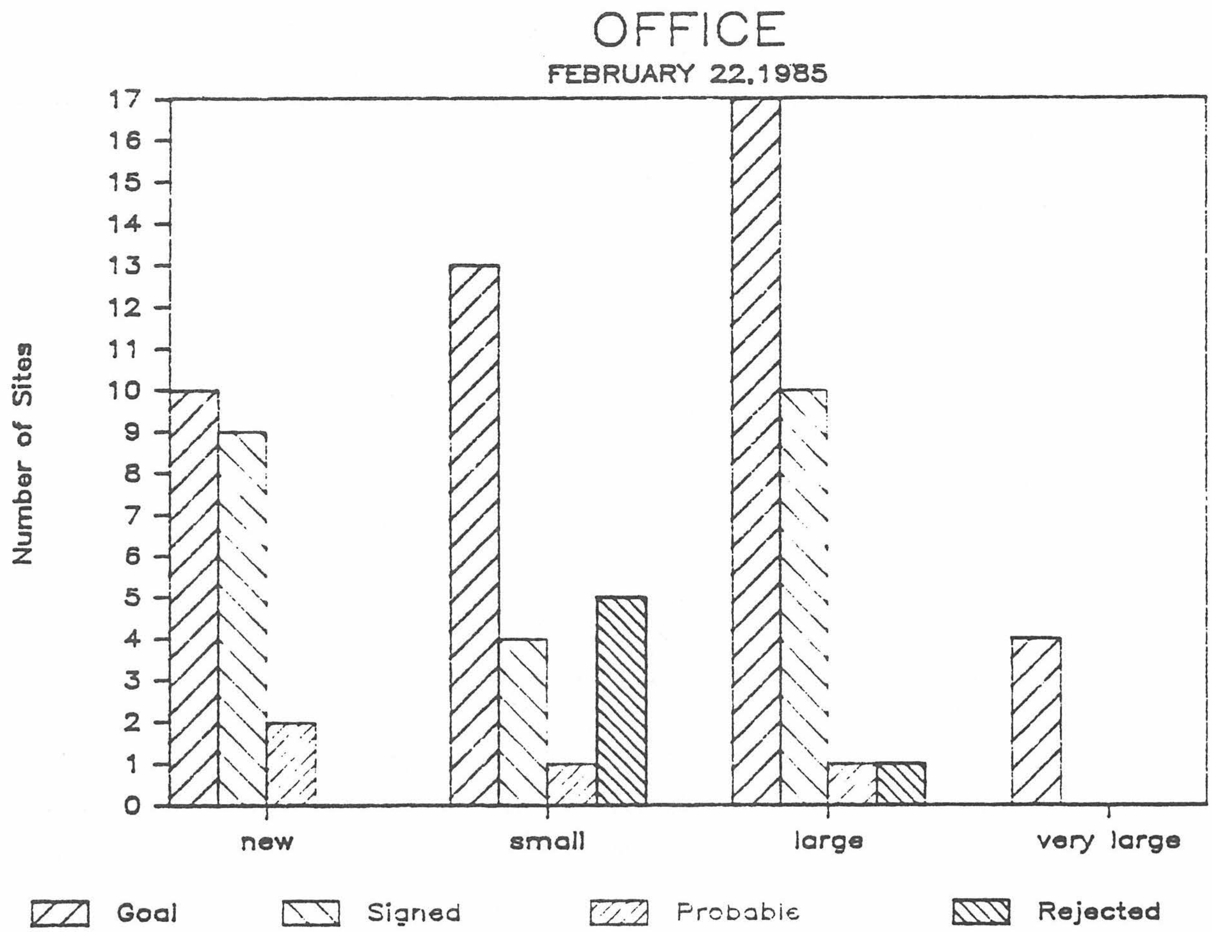
TOTAL
FEBRUARY 22,1985
Number of Sites
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Goal
Signed
Probable
Rejected
Recruitment Status



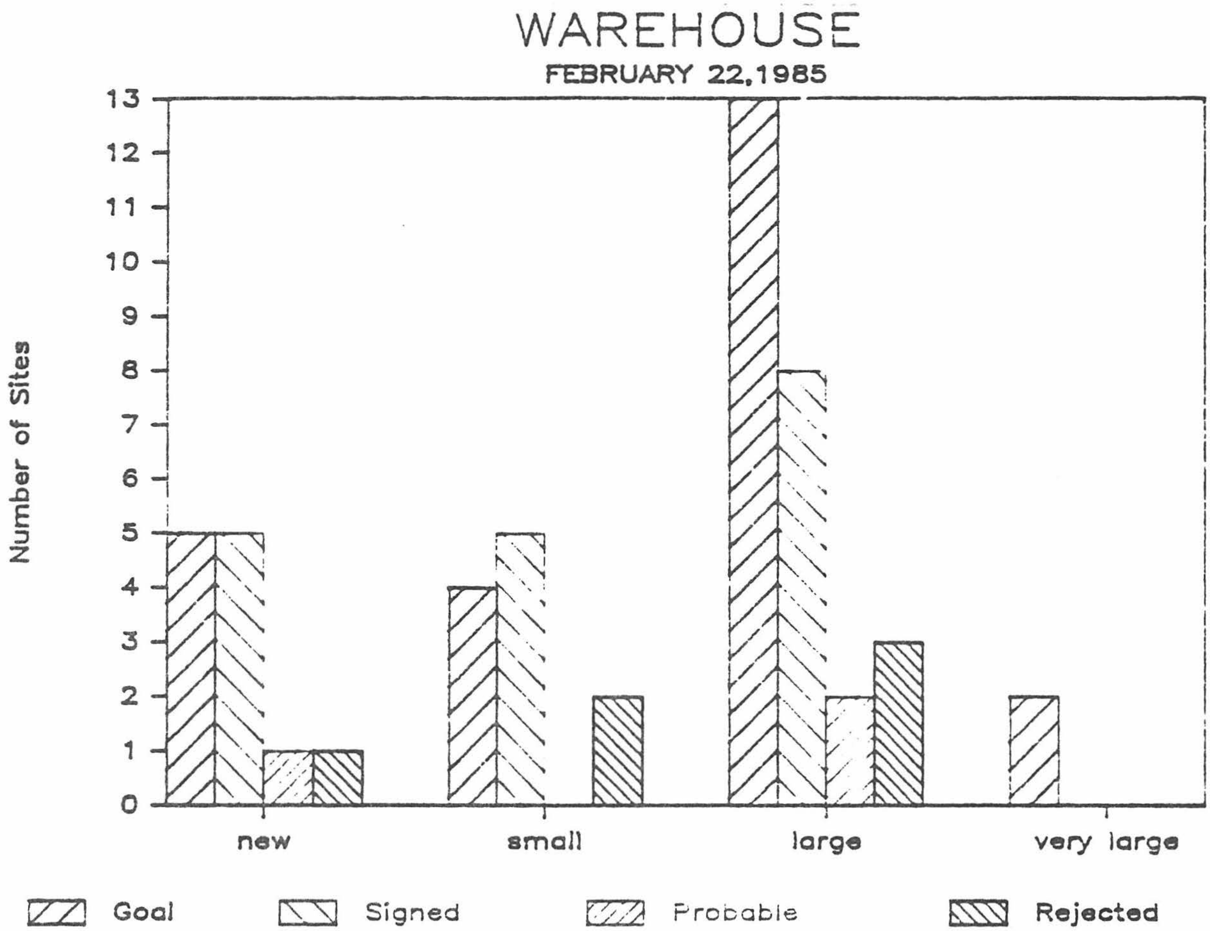
COMPOSITE
FEBRUARY 22,1985
Number of Sites
90
80
70
60
50
40
30
20
10
0
new
small
large
very large
Goal
Signed
Probable
Rejected


DRY GOOD RETAIL
FEBRUARY 22,1985
Number of Sites
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
new
small
large
very large
Goal
Signed
Probable
Rejected


GROCERY
FEBRUARY 22,1985
Number of Sites
0
1
2
3
4
5
6
7
8
9
10
11
12
13
new
small
large
very large
Goal
Signed
Probable
Rejected


OFFICE
FEBRUARY 22,1985
Number of Sites
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
new
small
large
very large
Goal
Signed
Probable
Rejected


RESTAURANT
FEBRUARY 22,1985
Number of Sites
0
1
2
3
4
5
6
7
8
9
new
small
large
very large
Goal
Signed
Probable
Rejected


WAREHOUSE
FEBRUARY 22,1985
Number of Sites
13
12
11
10
9
8
7
6
5
4
3
2
1
0
new
small
large
very large
Goal
Signed
Probable
Rejected

Exception/Rejection Form

CANDIDATE BUILDING REJECTION/EXCEPTION FORM

This form is used to document the reasons for which candidate commercial instrumentation sites are to be considered for rejection or exceptional treatment. Completion and approval is required prior to investigating alternative sites.

****

Building Address: ______________________________ Reference #: __________

Form submitted by: ____________________________________ Date: __________

****

Building is recommended for ....rejection o
..............................exception o

****

Reasons for Recommendation

Can not identify owner or person authorized to sign access aggreement o (1)

Owner refuses to grant access due to concerns regarding:
- privacy o (2)
- inconvenience o (3)
- legal liability o (4)
- safety o (5)
- aesthetics o (6)
- value o (7)
- other concerns o (8)

Tenant refuses to grant access due to concerns regarding:
- privacy o (9)
- inconvenience o(10)
- legal liability o(11)
- safety o(12)
- aesthetics o(13)
- value o(14)
- other concerns o(15)

Unsafe working conditions...o(16)

Inadequate documentation..o(17)

Mixed-use building..o(18)

Vacant building...o(19)

Confused end-use loads..o(20)

Excessive panels/circuits...o(21)

Unconditioned interior..o(22)

Manufacturing/industrial activity.....................................o(23)

Ongoing involvement in other projects.................................o(24)

Other unusual circumstances...o(25)

****

****

For each item checked list concern number and elaborate

Concern #   Comments

____
____
____
____
____
____
____
____
____
____
____
____
____
____
____

****

Estimate level of effort and calendar time needed to rectify concern

Description of action	Level of Effort	Schedule

****

Approved course of action: ____
____
____
____
____
____

By: ____ Date: ____________

****

Section 12

ELCAP: DATA ACQUISITION AND MANAGEMENT

E. W. Pearson*

INTRODUCTION

Any large-scale end-use metering experiment is sure to involve acquisition of a substantial quantity of data from a network of field stations over an extended period of time. Successful completion of such a project requires that several conditions are met. Data of good quality must be obtained from a high fraction of the experimental sites with few gaps in the time series records. These data must be verified and made available to analysts with a minimum of delay. It must be organized in such a fashion as to be readily accessible to analysts in a form which permits them to address issues related to the experimental goals. Finally, of course, each of these conditions must be achieved at reasonable expense.

Meeting these conditions is a particular challenge for ELCAP because of the very broad scope of the project. Among the complicating factors are the total size of the sample, number of measurements undertaken in individual structures, the fact that different measurement protocols are required for the various metering studies which compose ELCAP, and the logistical problems associated with the size of the Bonneville Power Administration service territory. These factors require development of a data acquisition and management system that is highly automated and reliable.

SYSTEM OVERVIEW

The three major components of the ELCAP data acquisition and management system are a microprocessor-controlled data logger, a central data acquisition microcomputer which polls the network of data loggers over telephone lines and carries out some preliminary data processing, and a minicomputer, on which final data processing takes place and on which the data base is maintained. Figure 12-1 shows the relation of these three components, and indicates the flow of data through the

*Pacific Northwest Laboratory, Richland, Washington.

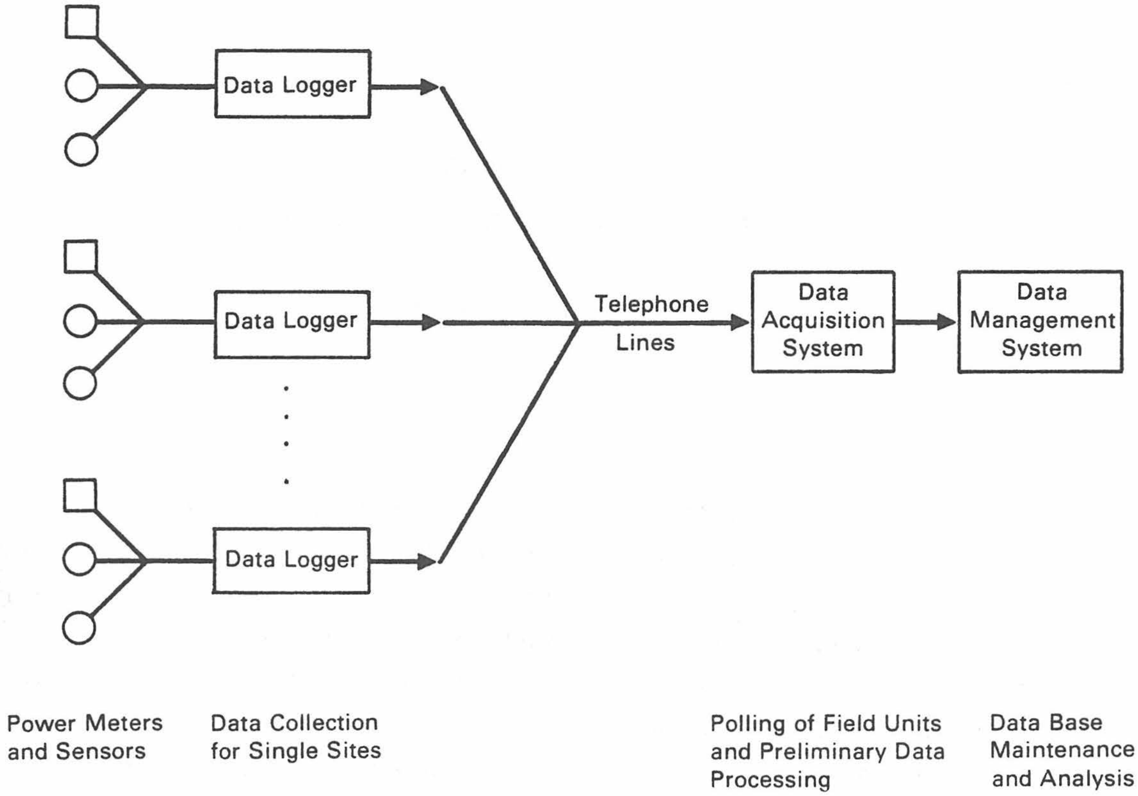


Figure 12-1. System Components

system. In the following paragraphs, the role of each component is briefly described, after which the data acquisition system and data base management system are treated in more detail. A more thorough discussion of the date loggers is available in Section 8 of these proceedings.

The field data loggers collect electric consumption data for individual circuits at building circuit panels. Also collected are a variety of sensor data; depending on the installation, internal conditions and meteorology may be monitored. Data logger operation is controlled by a number of parameters, which can be set remotely. Among these is the parameter which controls the temporal resolution of the collected data. The data loggers store records, which consist of consumption or sensor data averaged over the interrogation period, in on board memory. These records can be retrieved over a telephone line using the 1200-baud modem with which each logger is equipped. Existing telephone lines could be used for this polling; under ELCAP dedicated phone lines are usually installed.

The central data acquisition computer has three main functions. First, it polls the loggers according to an internally generated schedule. Second, it maintains the site specific parameters required to interpret the records obtained from the field loggers in terms of engineering units. Conversion of the data to engineering units is the final task of the data acquisition system.

Final data processing, maintenance of the data base and reporting functions are carried out on a minicomputer. Data transmitted to the minicomputer from the data acquisition system are checked and placed in the data base. An ancillary data base, containing characteristics and demographic data, is also maintained on the minicomputer. Facilities for data analysis are available on this system as well.

DATA ACQUISITION SYSTEM

The ELCAP data acquisition system is a dedicated Hewlett-Packard 9920 microcomputer configured with a number of peripheral devices. Figure 12-2 indicates the more important elements of this system, which includes a disc drive, a nine-track tape drive, a printer, a parameter entry work station and a number of modems and phone lines. Because of the size of the ELCAP network, and to satisfy a desire for redundancy, additional polling microcomputers connected via a controlling computer will be added; installation of this configuration, outlined in Figure 12-3, is planned for the first quarter of 1985.

The data acquisition system has a number of functions. First, it maintains the parameters required to convert the raw data obtained from the data loggers to engineering units and it supplies parameters remotely to the data loggers. Second, it polls the network, according to an internally generated schedule designed to avoid the loss of data. Polling is followed by preliminary data processing, in which the data are converted to engineering units and certain error conditions detected. Finally, data are archived and transmitted to the data base management system. The Pascal language software which carries out these functions, discussed below in more detail, was developed specifically for ELCAP.

Parameters maintained on the data acquisition system are of three types. One set of parameters controls the operation of the individual data loggers; these must be remotely deposited in the data logger memories by the data acquisition system. There are a small set of parameters, including telephone numbers, which are required by the data acquisition system for communication with the loggers. Last, there is a rather large set of parameters which is required to interpret the data obtained from the field units. This set includes specific scaling information for each

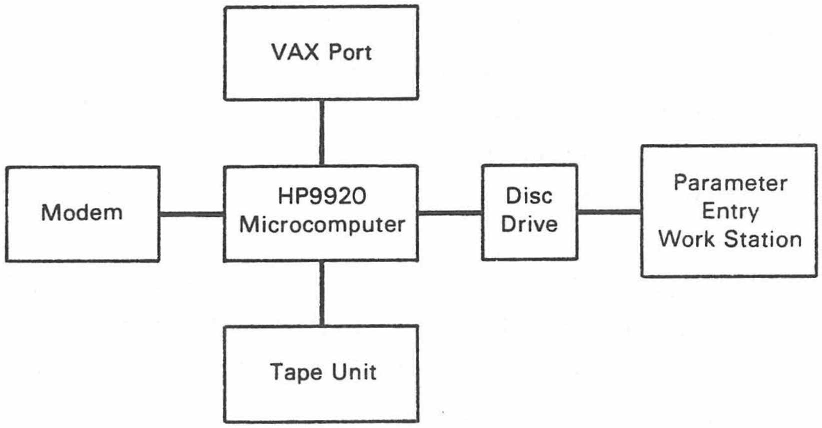


Figure 12-2. Data Acquisition System

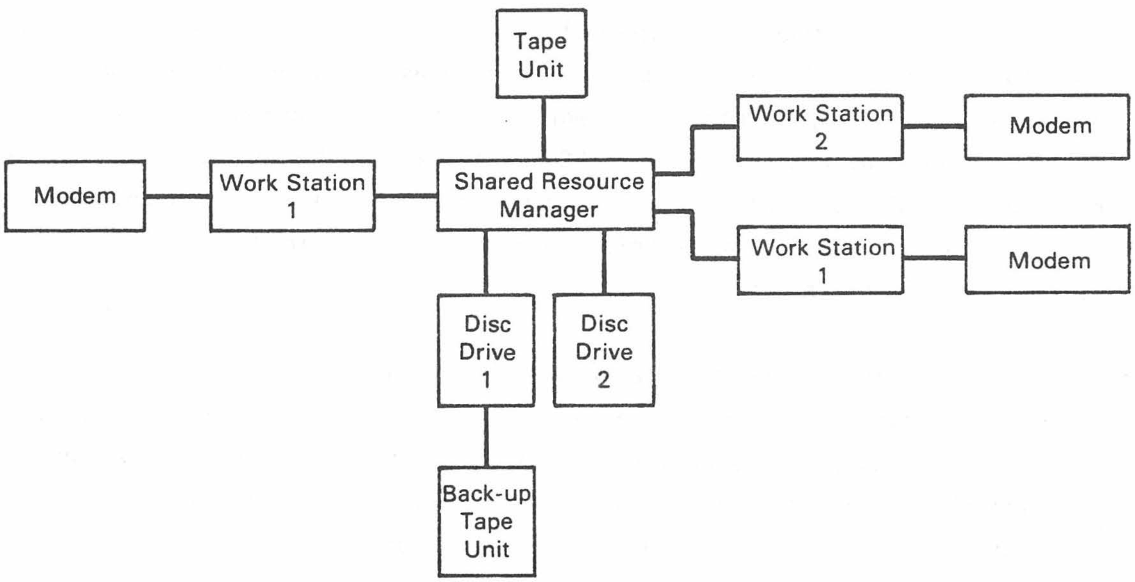


Figure 12-3. DAS - Final Configuration

channel. In our case, for energy channels, this scaling requires the knowledge of current transformer rating, reference voltage, and scaling resistor size.

Parameters are entered via a work station using a software utility designed to provide a convenient format and to minimize the chance of error. The software has the capability to maintain a number of generations of parameters for each logger, thus permitting the reprocessing of raw data from the archive with the proper set of parameters. Because data conversion parameters may change for any of a number of reasons, including modification of a building, a change in the complement of sensors attached to a logger, or simply correction of a previous error, this feature is quite valuable. Parameter tables can be obtained from the system on operator request.

The interrogation software has a number of components. A scheduler, designed to request the polling of each logger when its memory is roughly half full, controls the interrogation. As the number of records which can be stored in logger memory before data loss occurs varies depending on the complexity of a given installation, information about the number of channels in use (and, of course, the integration period) is required by the scheduler. The scheduler also provides the system operator with lists of sites in which interrogation is urgent if data loss is to be avoided.

The second major component of the interrogation software handles communications. Functions involved here include transmission of parameters to the loggers, verification of logger parameters on each polling, acquisition of data from the logger memory, error checking and reporting. The parameter verification is a check to determine that the logger has functioned as desired since it was last polled, and to detect drift in the logger clocks. The error checking is standard parity checking on the transmitted data. It serves the functions of avoiding damage to the data from telephone line noise and detecting errors in logger memory. After interrogation, a report of what data has been collected and of any errors or unusual conditions detected is prepared by the software. The communications software is designed to poll the loggers automatically; this process is usually carried out at night.

The final step before data can be transmitted to the data base manager is conversion of the data to engineering units. Making use of the appropriate parameters, electric consumption data is converted to watt hours (in the case of an interrogation period of an hour) and the sensor and meteorological data to appropriate units as well. At this point, checks for a number of error conditions, including lost time stamps on individual records, doubled records and missing records, are carried out.

Figure 12-4 indicates the major steps in the interrogation and data conversion procedures as described above. The performance of this system during the pilot phase and early portions of the main phase of ELCAP has proved to be quite satisfactory. The automated scheduling and reporting facilities minimize the need for operator intervention, and the choices available in parameters permit substantial

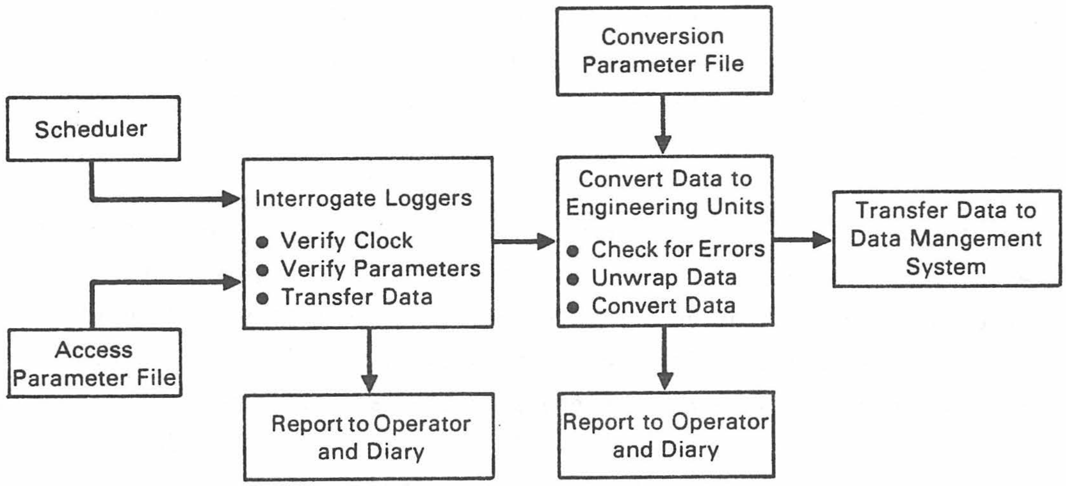


Figure 12-4. Logger Interrogation and Data Conversion

customization of individual field units. The ability to modify the data collection parameters of field units remotely greatly increases the flexibility of ELCAP data collection.

DATA MANAGEMENT

Once converted to engineering units, the ELCAP data are transferred from the data acquisition system to a Digital Equipment Corporation VAX® minicomputer. A number of functions are carried out on this minicomputer, including data verification, aggregation of the data to the end-use level, maintenance of the ELCAP data base, maintenance of an ancillary demographics and building characteristics data base, and reporting and analysis. The first four of these are the subject of the following paragraphs; description of the reporting and analysis system developed for ELCAP follows.

Figure 12-5 shows the flow of data once it has reached the VAX®. The first step is a formatting step, in which the data are converted to the format in which the ELCAP data base is maintained. During the first quarter of 1985 a facility for adding data quality flags to the individual data records will be added to this step. These flags reflect the status of individual field units at the time of data collection. Second, the data are subjected to verification procedures. Next, the data are

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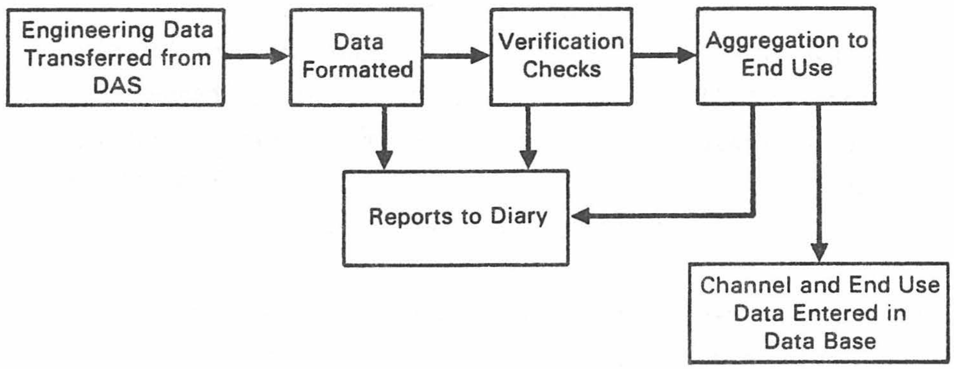

Figure 12-5. Data Flow on Data Management System

aggregated to the end-use level, and both the channel and end-use data are placed in the ELCAP data base. The utilities which carry out these steps each report to a common diary.

Of these steps, only the end-use aggregation requires further comment. Aggregation to end use is controlled by a set of equations for each site which give the end uses as sums of the channel data. For instance, the refrigeration load in a grocery store could be the sum of power drawn on a number of circuits. The aggregation equations for each site are drawn from the site measurement plans and maintained in a common data structure. One portion of the verification process is devoted to ensuring that these equations are, in fact, correct, and that assignment of channels to end uses is consistent from building to building.

We now turn to the question of data base design. In ELCAP the approach to data base design is different than that chosen in other early end-use metering projects. Most projects have been relying on a commercial package, often SAS (a powerful statistical analysis package with rudimentary data management facilities sold by the SAS Institute), to hold the data. Because of the eventual size of the ELCAP data base, the diversity of studies which comprise the program, and the unique and varied applications to which this data base will be put, we chose not to adopt that procedure. Rather, we chose to use the VAX® VMS file system as a passive data base manager, and to create an interface program designed to extract data sets tailored to a particular application from the data base.

The electrical power consumption and sensor data are maintained in disk files, each of which refers to a single building for a particular time period. The general organization of data is a tree structured data base, in which knowledge of a number of characteristics of a particular datum determine its location. This tree structure is indicated in Figure 12-6. The determinants of data location are class of structure, specific building, date, time, and, finally, channel number or end use. The first three of these are coded into file names. Within each data file the individual records are time stamped, and the fields corresponding to individual channels or end uses are identified by a header record.

In addition to the end-use and sensor data fields, individual data records include space for a number of data quality flags. These are intended to reflect logger status at the time of data collection, and will note any exceptional conditions (e.g., a power outage) which might affect data quality. In addition, failure of a record to pass data verification checks will be indicated in these flags.

The data base design described above provides a convenient and flexible method of storing data; with application of data compression techniques, it is economical as well. It admits the possibilities of study expansion and data base reorganization, and permits such operations as archiving to proceed quite smoothly. However, it does have the disadvantage that extraction of a data set from the data base is not as facile as would be the case were the utilities associated with powerful data base management software available. We have addressed this difficulty with development of a custom data interface utility.

DATA INTERFACE

Under ELCAP, end-use metering and sensor data at hourly resolution will be obtained from a large number of structures, grouped in several classifications, for a period of at least two years. It is quite clear that the first step in any sensible analysis effort will be to obtain either small subsets of the data or data aggregated across a number of buildings or at reduced temporal resolution. Even for metering efforts less ambitious than ELCAP, the amount of data collected will be sufficiently large that selection of useful subsets and data aggregation will be necessary to obtain a data set of manageable proportions.

These considerations have motivated our choice of a two component data management system for ELCAP. The first component is the simple data base design described previously. The second component is a data interface utility designed to extract appropriate data sets for a variety of different analyses from the data base. After discussion of the general analysis procedure which we envision, we turn attention to the data interface. Some examples of its products are presented to illustrate its use.

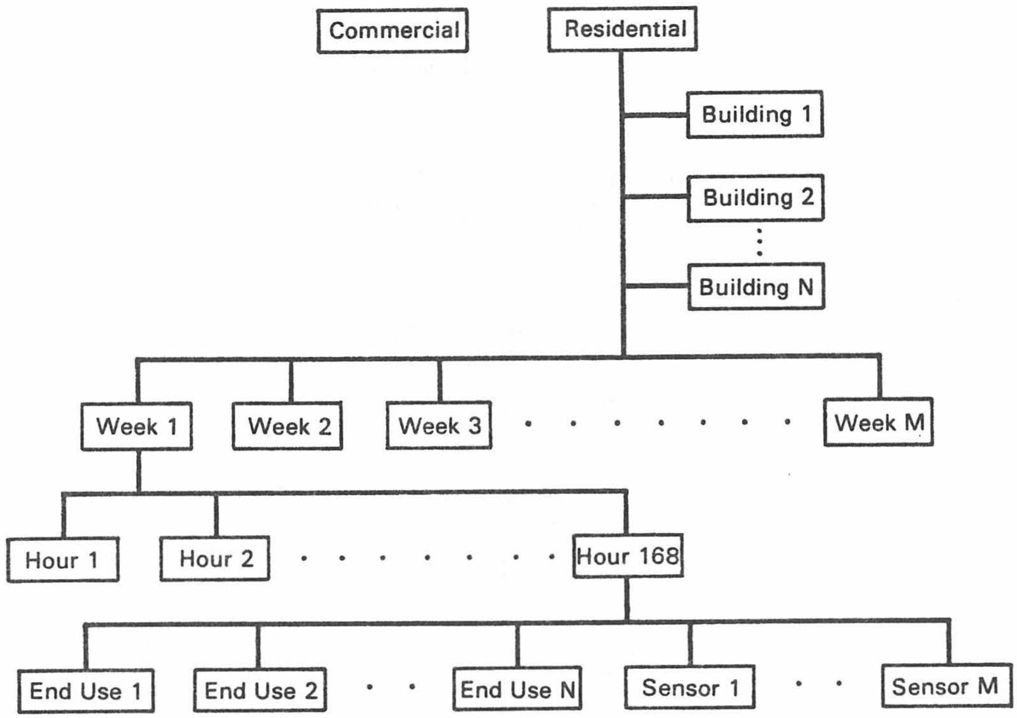

Figure 12-6. Engineering Data Base Structure

Figure 12-7 illustrates the general procedure which we anticipate will be followed for most analyses of ELCAP data. A list of buildings for which data are desired is drawn from the characteristics data base. The analyst determines the characteristics of the data set which he or she desires to have prepared, using the menu-driven interface program discussed below. This program extracts the data needed to fill the analyst's request from the engineering data base, perhaps incorporating demographic or characteristics data as well, and carries out the necessary computational operations to tailor the data set. Perhaps the resultant data set is itself the desired final product. If not, the interface program can be directed to format the data set for introduction into the analysis tool of the user's choice.

The current version of the interface program permits the data set to be tailored in a number of respects. Included are facilities for selecting the set of buildings and time window for which data are to be obtained, the level of temporal resolution of the output data set, the format of the output data set, and the set of channels or end uses for which data are to be placed in the output data set. In addition, capabilities are provided to support aggregation across sets of buildings, and to prepare average daily or weekly profiles. A number of control parameters may also be set by the analyst. Entry of control choices is made from a simple menu.

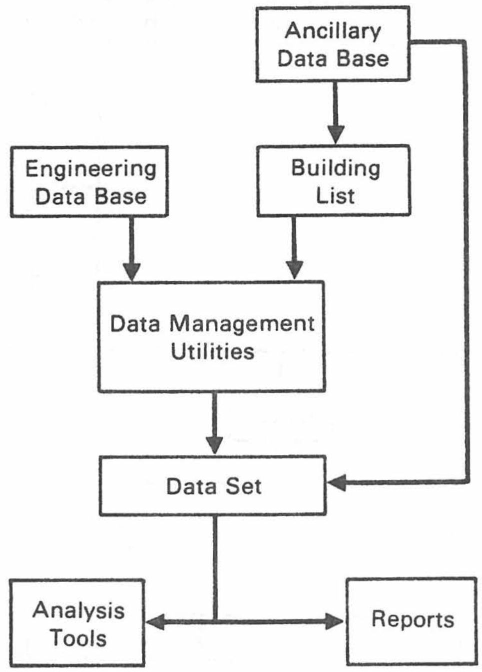

Figure 12-7. Analysis Procedure

Table 12-1 lists the parameters which may be set in the current version of the interface software, along with possible values.

To illustrate this procedure, suppose that we wish to obtain an average daily profile of energy use by the major end uses at hourly resolution for a single office building for the month of October. Table 12-2 presents the choices for parameters which would be required to obtain this data set, and Figure 12-8 provides a plot of the resultant profile. Figures 12-9 and 12-10 indicate products which may be obtained by exercising some of the other operations provided by the interface program. The former shows average daily loads for a grocery store during the month of December, while the latter is an aggregate average December weekday profile for a number of residences located in Eastern Washington.

As it now exists, the interface program makes it possible to extract any of the time series data from the ELCAP data base; if desired, a number of tailoring operations are possible. A substantial augmentation of the capabilities of this software is now under consideration, with a view towards making it a more complete research tool. Possible additions include the ability to carry out a set of standard

Table 12-1

PARAMETERS FOR CONTROL OF DATA SELECTION

Parameter	Function
Building List	List of structures for which data are required.
Error Report Level	Determines what types of data problems to report to user.
Output File	Controls location of output data set.
Starting Time	Earliest date for which data are desired.
Ending Time	Latest date for which data are desired.
Output Type	Controls format of output data set.
Time Interval	Temporal resolution of output data set.
Folding Period	Determines whether data are to be presented as a time series or as an average profile (e.g., a day or week).
Building Aggregation	Determines whether data from the individual buildings in the building list are to be aggregated, and, if so, whether a total or average value is desired.
Folding Aggregation	Determines whether folding operations should yield total or average values.
Select Time	Determines whether all data, only weekend data, or only weekday data are to be used in constructing the output data set.
End Use Type (1-n)	Determines which end use or sum of end uses is to be placed in each column of the output table.

normalizations, related either to weather or characteristics data, and the ability to preserve measures of variability across aggregations. In addition, a number of minor enhancements are in prospect.

Table 12-2

PARAMETERS FOR OFFICE BUILDING EXAMPLE

Parameter	Function
Building List	OFFICE.IN (File containing identification number of desired office building)
Error Report Level	SOME (Warnings of all important data irregularities will be made)
Output File	OFFICE.OUT (Arbitrary choice)
Starting Time	10/01/84
Ending Time	10/31/84
Output Type	GRAPHICS (Eventual product will be a plot)
Time Interval	ONE HOUR
Folding Period	DAY (average daily profile is desired)
Building Aggregation	AVERAGE (as we have only one building, this parameter has no effect)
Folding Aggregation	AVERAGE (The output data will be in terms of average hours)
Select Time	ALL (Weekdays and weekends are included)
End Use Type (1)	HVAC (First Column will contain space conditioning data)
End Use Type (2)	LIGHTING (Second column has lighting data)
End Use Type (3)	OTHER (Third column will contain balance of power consumption)

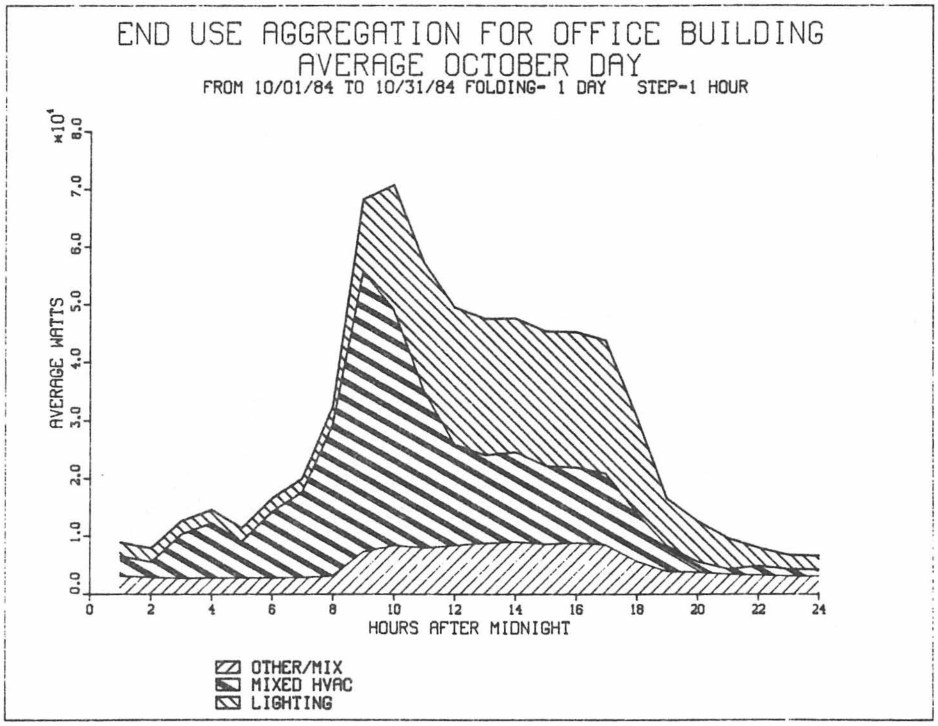

Figure 12-8. Electrical Consumption for an Average October Day in a Seattle Office Building

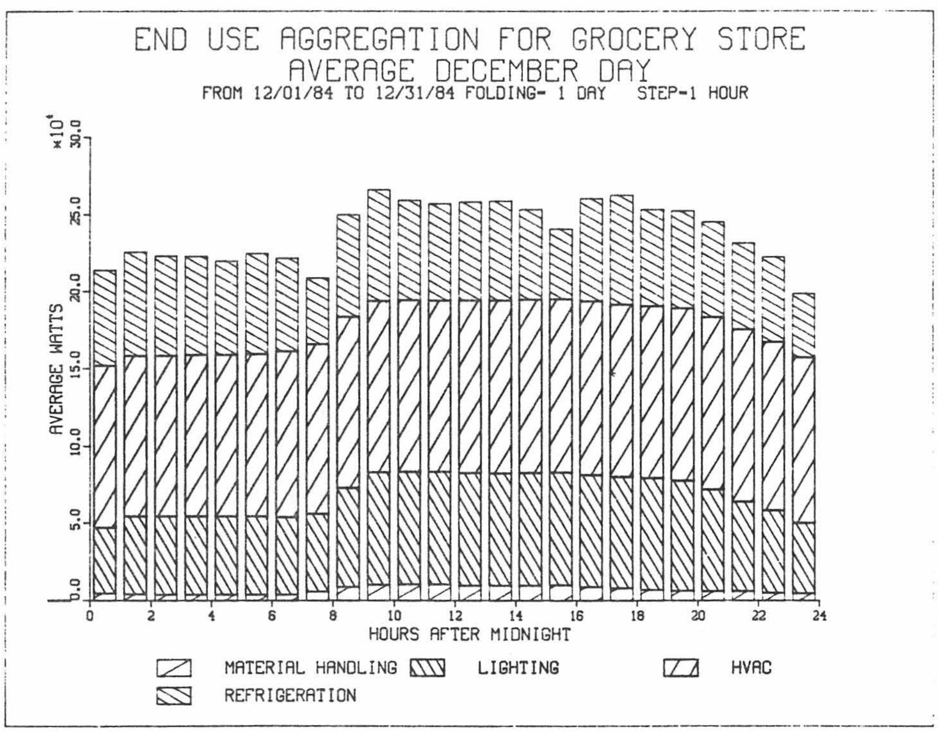

Figure 12-9. Electrical Consumption for an Average December Day in a Seattle Grocery

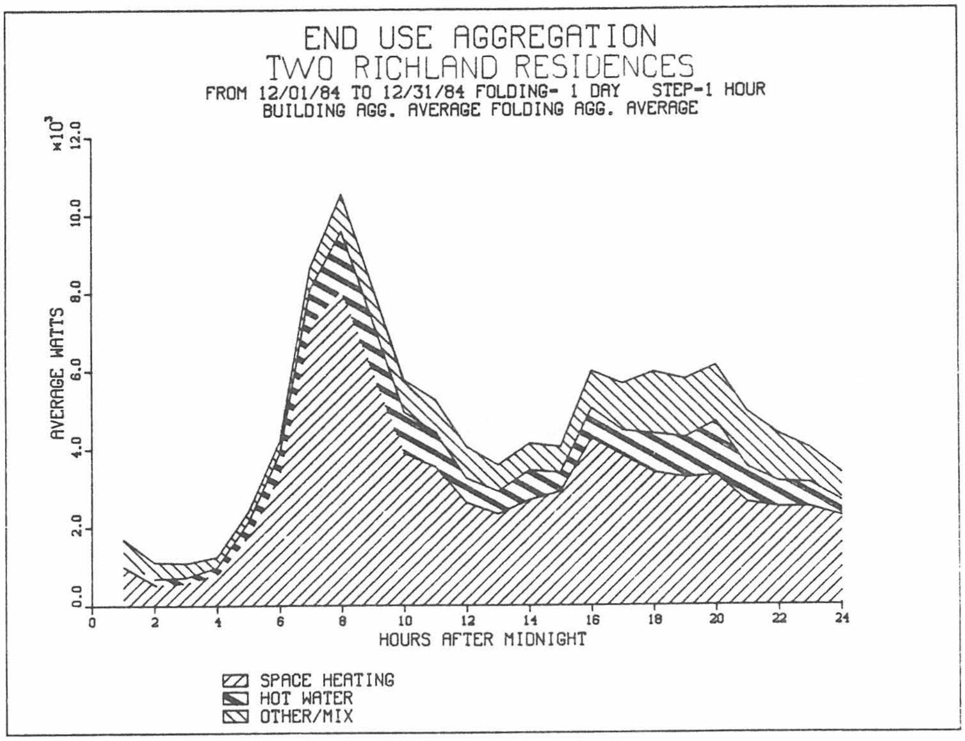

Figure 12-10. Aggregate Electrical Consumption Profile for Two Richland Residences

CONCLUSION

We have described the data acquisition and data management techniques developed during the early phases of the ELCAP project. A brief review of their performance during the initial phases of ELCAP, coupled with a discussion of the advantages and disadvantages of these techniques over other approaches, is needed to round out the discussion.

To date, the data acquisition system has functioned quite satisfactorily. Data have been retrieved from the field almost without incident for a number of months, the scheduling routine has avoided loss of data from units given into its charge, and the data have been satisfactorily converted to engineering units and transferred to the data management facility. In our opinion, the data acquisition system configuration described previously, along with its associated software, has every prospect of proving a robust tool for remotely collecting data from the full ELCAP network. In addition to reliability, it offers substantial flexibility; its ability to handle very different installations in the same experiment and the possibility of remotely modifying data collection parameters in the field units are quite valuable.

Of course, one learns something during the course of system development, and our system does have some disadvantages which we would avoid were we to repeat the development effort. The major difference in our approach would be in the area of computer hardware. The Hewlett-Packard 9920 which serves as the central data acquisition computer is a single-user, single-tasking machine. To provide the ability to conduct multiple simultaneous interrogations, an ability necessary to support the full ELCAP sample, either partial multitasking operating system software must be written or, as we currently plan, a network of polling work stations needs to be assembled. Although this latter approach is neither particularly complicated nor overly costly, it would have been simpler to have built the data acquisition activity around a multitasking computer system.

The software written for the data acquisition system is keyed to the particular field units employed in this study. Although it would be possible to employ the system with a different data logger, some recoding would be required; the extent of this effort would depend on the similarities in design of the field units. However, in combination with the data loggers employed for ELCAP, the data acquisition system seems to provide an effective and readily transportable solution to end-use metering problems.

The data management system, and in particular the interface utility, is not quite as complete as the data acquisition system. Indeed, we have planned from the beginning of the project to review the initial version and to develop a second version. Design of this second version is currently in progress. Nonetheless, we have garnered sufficient experience to be able to provide a preliminary assessment of our approach.

It seems quite clear to us that, like most classes of large-scale data acquisition projects, the operations that one will wish to execute on end-use data include both a standard and a unique component. Many of the desired operations should be readily practical in the context of standard commercial software; an example is the formation of simple statistical characterizations of the data. There will be, however, a large class of operations, such as weather normalization, which will not be so readily practical on a large scale in currently extant commercial products. Indeed, determination of methods for performing some of the operations in this latter class remains very much a research question. To accommodate these diverse needs, a flexible custom system seems necessary. In our opinion, use of, for instance, SAS as the principal data management and data analysis tool cannot provide the flexibility necessary for the wide range of research uses to which end-use data will be put.

The current version of our data interface seems to meet a number of important requirements. It provides facile access to the time series engineering and meteorological data, and permits the preparation of data sets of sensible size tailored for a variety of applications. Initial comments from users of this interface have been, on balance, favorable, and it appears that we have created a good first draft of a useful tool. We anticipate that the next version of the interface will be substantially more powerful, in large part because we will be building it on the basis of early experience with analysis of ELCAP data. It is our admittedly ambitious goal to create a system which will serve as at least a prototype of the standard environment for the analysis of end-use data.

ACKNOWLEDGEMENTS

Several PNL staff have been involved with the development of one or more of the ELCAP data acquisition and management systems. The operating software for the field units was written by George Schuster. Design and coding of the data acquisition system software has involved Karl Davis, Bob McBride, Steve Lucas, George Schuster and Charles Dunn. Work on the data management and interface software has been carried out by Nancy LaRiviere, Gregg Petrie, Brent Cooke and Carl Mears. This work was supported by the Bonneville Power Administration under a Related Services Agreement with the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

Section 13

DATA VERIFICATION IN END-USE METERING

Erik W. Pearson*
Gerald M. Stokes*
Scott Crowder*

INTRODUCTION

End-use metering involves the collection of data on physical phenomena. It is thus subject to the same difficulties that bedevil all experiments in the physical sciences, and requires the same attention to data quality that any properly conducted experiment should receive. In this paper we describe the verification procedures adopted for ELCAP. Most of the emphasis is placed on verification techniques which are applicable to any end-use metering experiment, although the examples are drawn from ELCAP and thus depend on the metering equipment and data acquisition protocols employed in that project.

This paper is organized around a number of topics. First we discuss the motivations for verification at various stages of an end-use metering project and the goals of verification procedures. We then describe several classes of procedures which can be used to meet verification needs. This material is followed by a description of our implementation of the two major classes of verification procedures currently employed in ELCAP. We then outline our management approach to verification activities, a matter of some importance in a project of large scope. Finally, we conclude with an assessment of our verification procedures.

VERIFICATION: MOTIVATIONS AND GOALS

The major motivation of data verification is to ensure that, at the conclusion of an experiment, the collected data is of known and reasonable quality. This condition will obtain only if the experimenters are confident regarding what quantities they have measured, and of the precision and accuracy which characterize their measurements. Confidence in the data requires that the entire experimental system be well characterized. In this section, we discuss what this requirement implies for ELCAP

*Pacific Northwest Laboratory, Richland, Washington.

and other end-use metering projects, and enumerate the stages of the data collection effort at which verification efforts are required.

A single end-use metering installation is quite complex. The components of the system which must be correct for quality data to be produced are listed below.

1. System hardware (instrument and sensors): Both generic problems, associated with the field unit design or fabrication or with one or more types of sensors, and specific problems, such as failed components, can be encountered.

2. Measurement Plan: The measurement plan indicates what sensors are being used to measure power consumption or conditions on each of the instrument channels. In addition, it provides a connected load survey for each circuit being monitored. Errors possible here include incorrect lists of the equipment operated on a given circuit or an incorrect record of the details of an installation (e.g., misidentification of the instrument channel to which a particular sensor is connected).

3. Installation: Any of a large variety of installation errors (c.f. Table 13-1 and associated discussion) may occur. Each of these will perturb the data in some characteristic fashion.

4. Communications Interface: It may not be possible to communicate reliably with a data logger, either because of faulty equipment or poor quality of information transfer over telephone lines.

5. Communications and Engineering Unit Conversion Parameters and End-Use Aggregation Parameters: The number of parameters required for communication, conversion of the data to engineering units and aggregation of the data to end use is large, and transcription mistakes are not unlikely.

An adequate verification procedure must address all of these possible difficulties.

In addition to the need to test all system components, there are two additional constraints on the verification process. First, because of the size of the ELCAP sample, verification procedures must be heavily automated. As will become clear in the following sections, the verification procedures we have developed require a substantial amount of work for even a single installation, and, if carried out manually, would be entirely impractical for a study a fraction of the size of ELCAP. Second, data collection under ELCAP, and under most end-use metering projects currently underway, is intended to continue for a substantial period. Consequently, the experimenters must monitor the system over an extended period of time to detect equipment failures or other problems which occur subsequent to the initial installation. Again, for any reasonable number of installations, the ongoing data verification must be automatic.

We have, then, three major requirements on a set of data verification procedures for an end-use metering project. The verification procedures must address all system

Table 13-1

FACTORS AFFECTING DATA QUALITY

Calibration:	Each channel is calibrated in the lab so that zero power yields a small positive signal; this offset signal is then subtracted from observed signals to yield the actual power consumed on a channel. This calibration may be affected by such installation details as the length of wire connecting a current transformer to the data logger. If the lab measured offset signal is different than that which obtains in the field then, under zero power conditions, a small positive or negative signal will result.
Unmonitored Load:	A channel which is actually drawing power may have been inadvertently unmetered. This condition will result in the power drawn on the main(s) appearing to exceed the power drawn by the individual feeder circuits whenever the unmetered channel is active.
Incorrect CT or Scaling Resistor Installed:	The interpretation of data from a channel on the data logger requires knowledge of the components used in the power metering. If an incorrect component is installed, the derived power consumption values will be incorrect by a constant factor. Errors in listing components in the measurement plan or data entry errors can be detected and resolved in the same fashion.
Incorrectly Installed Resistor:	If a resistor is not properly installed the data for all channels on a particular power meter card can be driven to high values.
Reversed CT:	One of the most common installation errors is reversing the leads on a current transformer. When power is drawn on the mismetered circuit, the affected channel, and perhaps other channels on the same power meter board, give negative readings. The same error can occur if a wire is passed through the CT in the wrong direction.
Voltage Reference of Incorrect Phase:	Each power metering channel is associated with a voltage reference. In the event that the voltage reference is of the wrong phase, the power measurement will be in error. Such an error will result in low readings on a particular channel; this should result in failures of the sum check.

Table 13-1

(Continued)

Measurement Plan:	The measurement plan may be in error by misassignment of channels, an incorrect connected load survey or in the list of equipment used to monitor a given circuit. Incorrect assignment of channels or connected load survey lead to implausible data being collected (e.g., a circuit on which a hot water heater is operated but which is labelled as a lights and convenience outlet on a measurement plan will yield incongruous results). Usually, an error in the equipment list will lead to erroneous conversion of field data to engineering data; most often the errors will be in the form of a multiplicative factor.
Parameter Errors:	Parameter errors can occur, either as a consequence of the measurement plan errors given above or due to failures in transcription. These errors can result in data effects of the sort described in the previous paragraph, and in incorrect end-use aggregation equations.

components, they must be largely automated and they must detect not only initial problems but also failures which occur during the course of operation. In response to these requirements, we have applied four sets of verification procedures.

CLASSES OF VERIFICATION PROCEDURES

The four distinct classes of verification procedures employed for ELCAP are pre-installation hardware testing, testing of the hardware at installation time, robust checks on the data based on redundant metering and reasonableness checks on the data. The last two of these are applied to data collected immediately after equipment installation, and will shortly be applied to all data as it is collected.

Here we briefly describe the hardware testing and hardware installation verification. We then discuss the data checks, concentrating on their general characteristics. Emphasis is placed on the data checks; much more so than the hardware checks, which are generic in value, they have been developed particularly for end-use metering work.

Pre-installation checking of hardware falls into two categories. First, critical components are tested and/or calibrated before installation of single field units. We test all of our current transformers and modems and calibrate several sensors prior to shipment of units to the field. Second, the data collection system as a whole requires demonstration of its performance prior to its installation on a wide scale; a sufficient number of units must operate for a sufficient length of time under field conditions to allow reasonable performance estimates. The motivations for these procedures are quite simple. It is a lot less expensive to troubleshoot an individual unit prior to field installation, and vastly less expensive to complete all necessary modifications to the field units prior to large-scale deployment. Employment of a hardware system which has performed successfully in previous experiments may obviate the need for explicit field testing.

Second, we undertake a set of checks as part of our installation procedures. Any of a large number of errors can be made at installation time. Indeed, during the course of a pilot study we found that some errors occurred in every installation on the initial attempt. Consequently, we have developed a testing protocol in which a standard electric current is applied through each current transformer while the response of the logger is observed in real time. This procedure, which we term a standard load test, is described in Section 9 of these proceedings. This test has in fact proven to be extremely effective at reducing the rate of installation errors.

We now turn to the subject of verification procedures which may be applied to metering data. There are three classes of such procedures which we have considered developing under ELCAP. These are robust tests, in which the results of redundant measurements are compared, reasonableness tests on the range and time cycling of the data, and filtering techniques, in which parameter estimates, formed on the basis of early time series data, are compared with later data. Procedures drawn from the first two of these classes are either in place or nearing final implementation; no procedures of the filtering type have yet been applied to ELCAP data.

As we define them, robust tests are those which a correct installation must meet; passage of our set of robust tests is a necessary, although not sufficient, condition for an installation to be considered correct. The simplest sort of robust test is one in which redundant measurements are taken. For an installation to pass such a test, these measurements must agree to within a tolerance which depends on the precision of the individual measurements. One simple example of such a test would be a requirement that the total power consumed in a building as monitored by a data logger agree with the reading of the utility meter for that site to within some appropriate precision. Application of such a test would require, of course, that all power circuits in the building be monitored by the metering equipment. A test of this type would be sensitive to errors in several of the system components, including the system hardware, the installation, and the parameters controlling conversion of the raw data to engineering units.

While the simple test indicated above would presumably indicate the presence of any gross errors, it is not particularly sensitive. In particular, errors in the measurement of power drawn on circuits where the consumption is modest relative to the total building consumption or where the major equipment is used only rarely are unlikely to be detected. In addition, the time resolution of the check, which is determined by how often one is prepared to read the utility meter, is likely to be substantially less than the time resolution of the data itself. A much more powerful test is obtained if the feeds on a breaker panel are monitored using the same protocol under which the individual circuits on that panel are monitored. Comparison of the total power drawn by the circuits with that drawn on the feeds at high time resolution is a very powerful tool for data verification. Our implementation of this test is discussed in the section on sum checking, where it is shown that not only does this test enable one to determine whether or not a given installation is producing good data but, in addition, allows for quite accurate diagnosis of faulty installations.

Of course, a robust test of the type above, although quite powerful at detecting installation or equipment problems, cannot determine whether a building measurement plan is correct. As long as the information regarding what metering equipment is installed on each channel is correct, no installation error has occurred, and the data logger is functioning properly, the robust test will be passed. It is unaffected by, for instance, an error in which a circuit labelled 'lighting' on the measurement plan is actually driving a refrigeration unit. Errors of this type may be found by reasonableness tests. In essence, tests of this class address the question of whether the observed data is consistent with what is supposedly being measured. Both total magnitude of the power drawn and cycling behavior on a circuit can be compared with what one would expect for the electrical equipment which is listed for that circuit on the measurement plan.

It is quite evident that these reasonableness tests are not as definitive as the robust tests described above, and that they require substantially more interpretation on the part of an analyst. For instance, some assumption regarding a reasonable range for the power consumption of a particular set of equipment is necessary to test the magnitude of power consumption for reasonableness, and failure of the data to fall within this assumed range can be due to a number of factors other than an installation or measurement plan error. Nonetheless, it has proved possible to devise a practical set of reasonableness tests which do indeed yield useful diagnostic information; we describe these in the section on reasonableness checks.

The final class of data verification tests which we have considered applying to ELCAP data fall under the broad headings of parameter estimation or filtering techniques. Our basic idea here is to use early data from a site to form some parameter estimates. Subsequent data would then be monitored for excursions from those estimates, and significant excursions then investigated as possible evidence of equipment failure. Of course, there are a large number of complicating factors which need to be considered in selecting parameters to estimate and in determining what constitutes a significant excursion. For instance, changes in schedule, season or business level could easily induce substantial changes in many energy usage parameters. In spite of these complications, and although we have not currently implemented any procedures of this type, and do not treat it further here, we consider parameter estimation to be a potentially useful verification technique.

SUM CHECKING--A ROBUST TEST

In this section we discuss the details of the sum checking data verification procedure which is applied to ELCAP data. To some extent, this discussion must be particular to the instrumentation used in ELCAP, because the techniques used have been designed to facilitate the detection of the installation errors which occur most frequently in the deployment of the ELCAP network. However, as the types of procedures employed could be readily modified for a project using alternate instrumentation, the discussion should be in any event useful.

As a matter of installation protocol, we redundantly meter all power consumption. To the extent possible, this is done by metering the feeders to each electrical panel and subpanel and all circuits on which power is drawn from each panel. This does not mean that an independent instrument channel with associated current transformer is required for each circuit; we regularly pass more than one load associated with the same end use through a single current transformer. A lighting panel for a single zone of a building is an example of where this can be done without compromising data resolution. Our protocols, nonetheless, mean an increase in the total number of instrument channels and current transformers required for each installation over what would be required in the absence of redundant measurements, and, therefore, do have some cost implications. Figure 13-1 is a schematic of our metering of a typical panel.

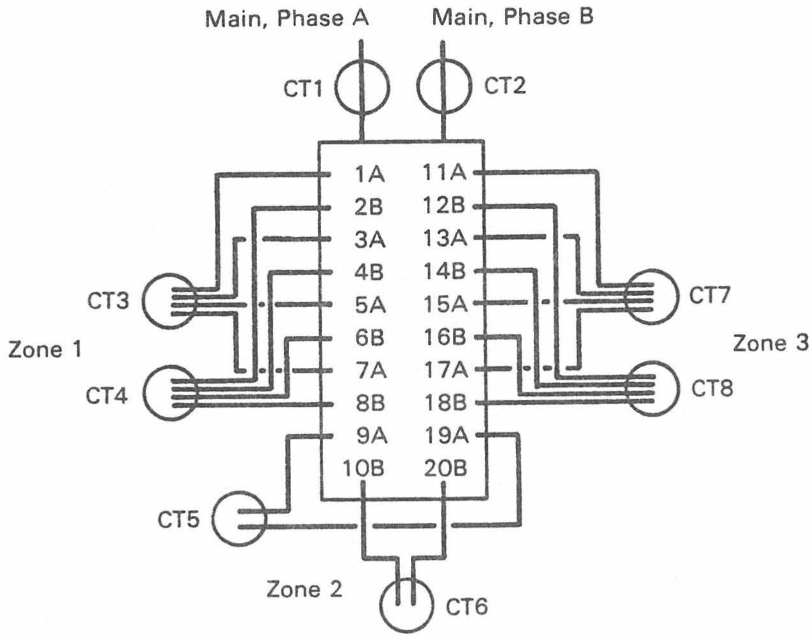

Figure 13-1. Typical 2 Phase Lighting Panel

Redundant metering allows us to create a set of equations, relating the power drawn on the feeders to the sum of the power drawn on the individual circuits. In the case of the example panel shown in Figure 13-1, if the instrument is exact and the measurements of infinite precision, we would expect that the two equations

$$P_1 = P_3 + P_5 + P_7$$

$$P_2 = P_4 + P_6 + P_8$$

would obtain. Here P_n is the power measurement on the instrument channel monitoring the nth current transformer, and each of these equations applies to one of the two phases. Failure of these equations to hold would be indicative of some installation problem or other measurement failure.

In practice, of course, the power measurements are of neither infinite precision nor perfect accuracy, and some discrepancies between the right- and left-hand sides of these equations will exist, even for entirely correct installations. Thus, in practice, the data must be tested against requirements of the type

$$| P_1 - P_3 - P_5 - P_7 | < TOL_A$$

$$| P_2 - P_4 - P_6 - P_8 | < TOL_B,$$

where the vertical bars denote the absolute value operation and TOL_A and TOL_B are tolerances, which may be determined based on the resolution and expected accuracy of the power measurements.

A simple protocol in which the individual data records are tested against equations of this type is sufficient to provide a pass/fail test which will detect the presence of most major installation errors. The test will be most powerful if the data are at high temporal resolution; at low resolution individual errors are less significant and, therefore, harder to detect. It is possible to use these checks, along with some additional information, to provide diagnostic information on installation and other errors. In the next few paragraphs we describe a computer program and some associated protocols which have proved highly effective in detecting specific installation problems based on sum checking. This capability is of utmost importance to ELCAP, or indeed any large-scale metering effort, due to the sheer impracticality of examining a substantial fraction of the data by hand and the economic desirability of including specific repair instructions when dispatching repair teams to the field.

To design a diagnostic tool, it is first necessary to determine the common installation errors and their effects on the data. The set of common errors will depend on the instrument being used in the study and, to a lesser extent, the installation protocol being followed. We gained a great deal of experience during the course of a pilot project, which resulted in a revised set of installation procedures, some modification of our hardware and a lengthy list of possible problems. In Table 13.1 we list the most common of these problems, along with the fashion in which the problem manifests itself in the data. This Table is far from exhaustive, and is intended largely to provide examples via which we can demonstrate techniques for remote diagnosis of site problems.

The sum checking verification software developed for ELCAP carries out a number of functions designed to determine whether any of the problems listed in Table 13-1 are present in a particular installation. Several days of data taken at five- or fifteen-minute time resolution are examined, record by record, to determine whether the sum check equations are met. A table of all records which fail each sum check equation is prepared, along with a list of the power metering channels active during the time period to which the record pertains. Figure 13-2 is an extract from such a list.

To provide diagnostic capabilities, a number of additional tables are prepared as well. First, there is a list of the minimum and maximum power values found on each channel throughout the period from which the data records were drawn. Negative minimum values, and nonzero minimum values for channels which may be expected to be at least intermittently quiescent are usually indicative of an incorrect offset calibration error. Additionally, a list of uniformly inactive channels is prepared.

Next, tables indicating the proportion of records reflecting activity on a given channel which fail the sum check and the proportion of records which fail the sum check in which a given channel is active are prepared. If a channel is misscaled, due to installation of incorrect components, a loose resistor, or other error, then it will show up near 100% in the first of these tables. An example is given as Figure 13-3. In this example, the data suggest that the source of any discrepancy might well be channel 29, although, for high time resolution data, a really badly scaled channel would show up near 100% in such a tabulation. Additional tables indicating the distribution of differences between a main and its feeder channels are also useful.

The output from the sum check program concludes with a number of statistics regarding the proportion of records which failed the sum check and the magnitude of the discrepancies. In the absence of any clear problem detected from looking at the results of the sum check program, these values are examined to determine whether or not they fall within certain preset limits; provided they do, the installation is deemed to have passed the sum check tests.

The sum checking software provides, in addition to the tabular output described above, a hypothesis testing facility. In particular, inferred offset errors and scaling problems can be eliminated from a data set, which is then subjected to the sum check procedure a second time. Dramatic improvement in the proportion of records meeting the sum check criteria is a sign that the diagnoses are correct.

Reinspection of Table 13-1 indicates that the expected consequences of the common errors listed there may be detected from the information obtained via the sum

A: (C25 - 161) = C26 + (C27 - 48) + .5•C28 + C29 + C30 + (C31 - 12) + (C32 - 24) + C35 + C36

B: (C33 - 161) = (C27 - 48) + .5•C28 + C34 + C35 + C36 + C37 + C38 + C39 + C40

pH	Day	Min	Mn A	Fdr A	Diff	% Dif Active Channels for A		Mn B	Fdr B	Diff	% Dif Active Channels for B	
A	1489	1015	2730	2558	172	6	C26 C27 C28 C29 C32 C36					
A	1489	1020	1606	1425	181	11	C26 C27 C28 C32 C36					
B	1489	1040						5461	5655	-194	3	C27 C28 C34 C35 C36 C38 C39 C40
B	1489	1045						7388	7635	-247	3	C27 C28 C34 C35 C36 C38 C39 C40
B	1489	1050						7388	7691	-303	4	C27 C28 C34 C35 C36 C38 C39 C40
B	1489	1060						5461	5626	-165	3	C27 C28 C34 C35 C36 C38 C39 C40
B	1489	1065						4658	4920	-262	5	C27 C28 C35 C36 C38 C39 C40

Figure 13-2. Difference Records -- Phases A and B

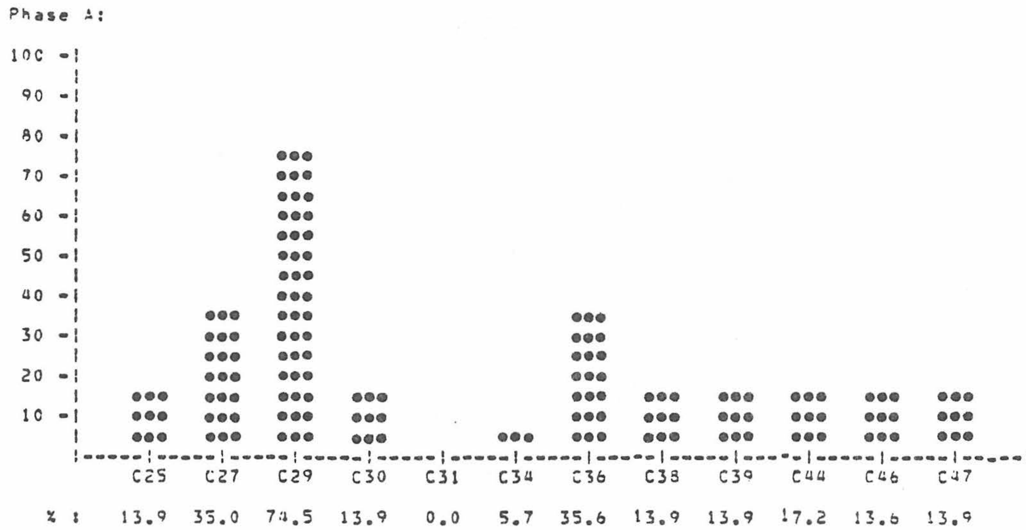

Figure 13-3. Percent of Time Record Fails When Channel is on

checking software. We have found in practice that the diagnoses reached by an experienced analyst with the aid of this software are almost always correct, and that installations may be corrected based on this information. Again, the sum checking techniques are most powerful when applied to data at high temporal resolution, since, at low resolution, incorrect channels which contain infrequently operated devices with short cycle times may have only a weak impact on individual data records. In addition, it is desirable to have as few channels as possible included in each sum check equation, since the tolerance within which the equation may be expected to hold is an increasing function of the number of channels involved, and since it is easier to sort out a misbehaving channel from a small, rather than a large, group.

As a final note, the procedures described here are in several respects ideal for ongoing data verification. Because the procedures are so highly automated, and because significant equipment failure will almost surely be detected by these checks, it is both practical and profitable to apply them to data as they are acquired and entered into the data base. It is our intent to subject all ELCAP data to this procedure; we anticipate substantial savings in staff time and improvement in data quality from so doing.

REASONABLENESS CHECKS

Although the robust verification procedure described in the previous section is capable of detecting most installation errors, it provides only limited information about errors on the measurement plan. Diagnosis of such errors as incorrect scaling and unmonitored loads can be obtained from the robust check. However, misassignment of channels to end uses or incorrect lists of equipment on a particular channel will not affect the sum check results. In addition, sum checking is of minimal use in testing external meteorological or internal condition sensors. We have devised a set of reasonableness checks, again implemented in a software package, to address measurement plan and sensor problems.

The reasonableness checks consist of determination of the maximum and minimum power readings on each channel, comparison of these against predetermined estimates, aggregating hourly data to arbitrary periods and determination of the proportion of peak power consumed during each of these periods. Both of these tests are intended to ensure that the electrical equipment operated on a given circuit has been correctly identified on the measurement plan. The first ensures that the range of power consumption is reasonable, while the second addresses the question of whether or not the observed diurnal cycling is consistent with the expected operation of the equipment in question.

It should be noted that both of these tests are subjective in nature, since they involve judgements as to what range of power consumption and cycling behavior is to be expected. In particular, application of these tests requires an analyst to estimate both a sensible range for the maximum power reading on each channel, based on the equipment inventory included in the measurement plan, and the diurnal cycle for the equipment operation. Consequently, these reasonableness tests are not as definitive as the sum checking tests described in the previous section. Nonetheless, our early experience has indicated that they are in fact quite useful.

It is our intention to incorporate checks on the meteorological and interior condition sensors in the reasonableness checking software, as these checks will take the same form as those described above. In particular, temperature, insolation and wind speed measurements will be compared with tables based on season and climate zone. These checks on the meteorological sensors will be included in the ongoing data verification procedures.

As may be inferred from the discussion above, the reasonableness tests are still in an experimental stage. We are in the process of assessing the utility of the tests described here, and may well modify them. Although it has proved fairly straightforward to devise a sensible set of reasonableness criteria for residential metering, the greater complexity of commercial buildings provides a substantial challenge.

ADMINISTRATIVE PROCEDURES

Because of ELCAP's size, verification and maintenance activities could easily get out of hand in terms of consumption of staff time and money. Consequently, we've paid some attention to administering these activities in sensible fashion. This section provides a brief description of the procedures we employ.

Problems with a given installation, or with any of the hardware or software components required to operate the entire system, can be noted by any of a large number of staff during the course of any of a large number of activities. When a staff member detects a problem, he or she describes the problem on a standard form and forwards the form to a small committee which has responsibility for determining corrective actions. The majority of reports to this committee do originate in the verification process, but there are a number of other sources, including the data acquisition task (problems with communications), the measurement plan review task (internally inconsistent measurement plans), or the field installation teams.

The committee which receives reports of problems has a number of responsibilities. First, it determines what corrective action is required. For problems involving single sites this usually involves approving the diagnosis supplied from the verification process and, if warranted, planning a field visit. Next, it coordinates field visits to ensure that all known problems are corrected at each site in a single visit and that all visits to a given region are scheduled in a single field trip. Finally, it tracks the performance of the major components of the metering system with a view towards detecting any systematic problems. To this end a data base of problems and corrective actions is maintained. The committee includes individuals familiar with the metering hardware, installation process, measurement plan review, data acquisition and communications, and verification so that expertise suitable to all classes of problems is available.

CONCLUSIONS

During the early phases of the pilot portion of ELCAP, we realized that substantial effort would need to be devoted to data verification. Through analysis of early data, we determined that it is indeed possible to create verification procedures with substantial diagnostic capabilities. Although some of our verification procedures are still under development, our experience to date indicates that we have the capability of assuring the quality of end-use metering data.

Our experiences can be summed up with the following recommendations:

1. For any large-scale metering project, data verification must be highly automated; failure to automate will lead to enormous demands on staff time.

2. The single best assurance of data quality is the execution of redundant measurements at high time resolution. Implementation of redundant measurements provides powerful diagnostic capabilities.

3. Installation of metering hardware is a complex task, and errors should be expected. Real time tests during installation substantially reduce the frequency of many common installation errors, but do not eliminate them.

4. There are many system components which can fail, and verification procedures must be developed which detect failures in any of them.

5. Even with substantial automation in data verification and careful development of installation procedures, data verification is a time consuming and expensive task for which provisions must be made in project plans and budgets.

It is indeed possible to obtain data of known and reasonable quality in an end-use metering experiment. To do so, however, requires substantial dedication to data verification. If an organization attempting to carry out an end-use metering effort is not prepared to devote the necessary time, effort, and money to this task, the chances are excellent that the project will be a failure.

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PRESENTATIONS AND REPRINTS