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A Protocol for Monitoring Energy Efficiency Improvements in Commercial and Related Buildings

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Prepared for the
Office of Buildings and Community Systems
U.S. DEPARTMENT OF ENERGY
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OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
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Energy Division

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Existing Buildings Efficiency Research

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Acknowledgments

This protocol is based on input from several different sources. The most important influence is the work that was performed for the End-Use Load and Conservation Assessment Program (ELCAP) of the Bonneville Power Authority in the Pacific Northwest to develop methods for classifying commercial buildings. The efforts of interest were performed under the direction of Pacific Northwest Laboratory, and Richard Mazzucchi, who also has served as an advisor for the development of this protocol, was the person most directly responsible for that work.

A second important influence was provided by Mashuri Warren, formerly of Lawrence Berkeley Laboratory, who developed some of the introductory material and provided a proposed draft of the Building Description Data Form material. This proposed draft of the Building Description Data Form material was based on work performed by Harry Misuriello, of W. S. Fleming and Associates, for building monitoring studies in Southeast Asia. This proposed draft was modified substantially to arrive at the present document forms, but the nucleus of the material was provided from the work of Misuriello and Warren.

The descriptions of common experimental designs were originally developed by Jay Burch of the Solar Energy Research Institute as part of work on a chapter on *Building Energy Monitoring* for the *ASHRAE Handbook* and are adapted here for this protocol.

The energy improvement codes were taken almost exclusively from codes that were described in a presentation made by the Energy Technology Engineering Center (ETEC), a Department of Energy (DOE) center. These codes have been used to classify energy conservation measures that have been submitted for grant approval under the Institutional Conservation Program ("Schools and Hospitals") administered by DOE. These codes and descriptors were modified slightly in a few cases. We wish to thank George Jackins, of Engineering Resource Group, Inc., for supplying a copy of these codes.

The concepts covering requirements for transfer of data using computer media (Data Transfer Form) were taken from an Oak Ridge National Laboratory *Performance Improvement Project* (PIP 86-3) report prepared by the Environmental Sciences Division.

EXECUTIVE SUMMARY

Developing a widespread understanding of how energy is used and the types of services it provides in commercial and related (light industrial, large multifamily, mixed commercial/residential) buildings has proved to be difficult. This difficulty arises from the diversity of sizes, uses, schedules, and building types, the changing use of buildings, and the mixture of uses within individual buildings. Recent research indicates that commercial buildings can be categorized reasonably (Briggs et al, 1987; McLain et al, 1988), allowing increased understanding of factors affecting energy use. This document describes a protocol that addresses basic measurement and reporting requirements for studies of costs and savings from energy efficiency improvements in commercial buildings. Use of the protocol is intended to promote more consistency in how commercial buildings are described (which allows categorization) and how results are reported from such studies. Improved consistency is intended to lead to increased understanding of field performance monitoring results.

This protocol has been developed for the Existing Buildings Efficiency Research (EBER) program of the Department of Energy (DOE) for use on field monitoring studies of energy improvements for commercial buildings. Significant advances have been made in methods for organizing and documenting metering studies in commercial buildings in this decade. This protocol builds on these advances and is intended to serve as a guide for future improvements.

The protocol is also intended to support the development of long term energy performance tracking methods, with building descriptive information supporting comparisons of efficiency between buildings. Research will be needed to determine those factors that describe variations in consumption between buildings, and data collected using this protocol will provide an opportunity for beginning that research.

A previous protocol guideline was developed for this DOE program covering studies in single family buildings (Ternes, 1987). The protocol discussed here is similar to the previous document in that it discusses data requirements for monitoring studies. However, since there are many types of commercial buildings (single family buildings are essentially one type), and since there is a diverse array of potential efficiency improvements; the approach taken must differ as to how specifically measurement procedures can be described, how buildings are described, and what range of analysis can be considered. The important link between the two documents is the need for guidelines to direct field performance energy measurement studies.

The strategy used for this protocol is to specify data requirements for describing the measured field performance of efficiency improvements in buildings. The requirements cover description of a project, description of the analysis and reporting of specific analysis results, minimum requirements for measured data, and description of the building or buildings that were monitored through use of a building description data set. Sharing the cost of field monitoring projects with other groups or associations having similar interests has been and is expected to continue to be an important part of the EBER program. Since data are expected to be collected by different investigators, the protocol helps to ensure that data from projects are reasonably consistent and comparable.

The requirements for reporting data include four general categories:

- Project or Program Description – general information including identification of the project or program, why it was conducted, and what improvements were made to the buildings or systems studied
- Analysis Methods and Results – summary of analysis (evaluation) methods, experimental design, and project results
- Performance Data – summary of monthly (billing) data, submetered or detailed energy consumptions, inclusion of demand data (if any), and temperature and weather data
- Building Description Data – survey data which describe each building and associated building systems, functional use areas, tenants, schedules, base energy data, and energy improvements

Forms and instructions for completing the forms are provided in this document, and all data sets generated using this protocol require completion of: a project description form, building description data forms, a performance data requirements form, and an analysis methods and results summary form.

We recommend that the EBER program begin using this protocol for studies of energy efficiency improvements in commercial and related buildings. After initial data collection activities, significant analysis of the benefits of this protocol for monitoring the performance of energy efficiency improvements is needed. We have attempted to balance the need for information with the need to keep a simple, workable scheme for data collection. The approach presented in this document should be used as the starting guide for field trials.

We recommend that submetered—or more detailed than monthly—energy use data be provided for most projects. More detail is desirable since typical billing data (recorded monthly) do not permit discernment of many of the driving factors which influence energy use. In addition, many months may be required to collect enough data to achieve desired confidence levels for results (Ternes, 1987). Lastly, providing submetered or detailed data will allow additional analysis to be performed to provide more feedback to protocol users.

Certain quality tests are needed to evaluate the usefulness of the information required under this protocol. It is likely that field procedures will need to be developed to handle difficulties that arise in interpreting the information needed for the forms. The qualifications needed for field personnel should also be determined through field tests. Cross checks of variations in data collection results for specific buildings should be conducted to evaluate the potential impact of field data collection personnel on the results achieved.

Significant development of analysis techniques is still needed to support studies of energy efficiency in commercial buildings. The issue of recommended techniques must be evaluated further as testing of the proposed methods continues (MacDonald and Wasserman, 1989).

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ABSTRACT

This document describes a protocol that addresses the basic measurement and reporting requirements for studies of costs and savings from energy efficiency improvements in commercial and related buildings. Significant advances have been made in methods for organizing and documenting metering studies in commercial and related buildings in this decade, and this protocol builds on these advances. Use of the protocol is intended to promote more consistency in how commercial buildings are described and how results are reported from such studies, which is intended to lead to increased understanding of field performance monitoring results. This protocol has been developed to support efforts of the Existing Buildings Efficiency Research (EBER) program of the Department of Energy. The strategy used for this protocol is to specify data requirements for describing the measured field performance of efficiency improvements in buildings. The requirements cover description of the projects, description of the analysis and reporting of specific analysis results, minimum requirements for measured data, and description of the monitored building(s) by use of a building description data set. We recommend that the EBER program begin using this protocol for studies of energy efficiency improvements in commercial and related buildings.

INTRODUCTION

Developing a widespread understanding of how energy is used and the types of services it provides in commercial and related (light industrial, large multifamily, mixed commercial/residential) buildings has proved to be difficult. This difficulty arises from the diversity of sizes, uses, schedules, and building types, the changing use of buildings, and the mixture of uses within individual buildings. These factors make comparison of energy performance and energy savings results from energy improvements more difficult to compare and hard to categorize. Recent research indicates that commercial buildings can be categorized reasonably (Briggs et al, 1987; McLain et al, 1988), allowing increased understanding of factors affecting energy use. This document describes a protocol that addresses measurement and reporting requirements for studies of costs and savings from energy efficiency improvements in commercial buildings. Use of this protocol is intended to promote more consistency in how commercial buildings are described, the types of results developed, and how results are reported in these types of studies. Improved consistency is meant to promote increased understanding of field performance monitoring results of energy improvements in these buildings. The consistency obtained by using the protocol is intended to improve categorization and comparisons of energy use and savings between buildings, support continued advances in reporting of energy improvement results, and provide data for estimation of regional benefits from those improvements.

The protocol is also intended to support the development of long term energy performance tracking methods, with building descriptive information supporting development of building categories for comparisons of efficiency between buildings in similar categories. Many larger facilities use energy tracking to compare current energy performance with historical consumption, and some type of tracking should be extended to a larger population of buildings. Research will be needed to determine those factors that describe variations in consumption between buildings, and data collected using this protocol will provide an opportunity for beginning that research.

This protocol has been developed for the Existing Buildings Efficiency Research (EBER) program of the Department of Energy (DOE) for use on field monitoring studies of energy improvements for commercial buildings. Development of the protocol was selected as an important task within the overall program as part of initial planning efforts (MacDonald et al, 1986). Significant advances have been made in methods for organizing and documenting metering studies in commercial buildings in this decade. This protocol builds on these advances and is intended to serve as a guide for future improvements to requirements for field monitoring studies of energy efficiency improvements.

A previous protocol guideline was developed for this DOE program covering studies in single family buildings (Ternes, 1987). The protocol discussed here is similar to the previous document in that it discusses data requirements for monitoring studies. However, since there are many types of commercial buildings (single family buildings are essentially one type), and since there is a diverse array of potential efficiency improvements; the approach taken must differ as to how specifically measurement procedures can be described, how buildings are described, and what range of analysis can be considered. The important link between the two documents is the need for guidelines to direct field performance energy measurement studies.

Protocols provide directives for particular projects or programs, and they also serve as examples of recommended practice. The requirements described in this document serve the needs of the EBER program for conducting field studies of energy improvements, but we hope it will also be useful to others performing similar studies or developing related monitoring guidelines.

NEED FOR MONITORING PROTOCOLS

Field performance monitoring of building energy systems is increasingly employed to obtain data required for making decisions about energy and power use in commercial and related buildings. Data from field monitoring studies are used by a diverse community including energy suppliers, energy end-users, building systems designers, public and private research organizations, equipment manufacturers, and public officials involved with the regulation of residential and commercial building energy efficiency. While the range of desired goals and issues these various constituencies work under is diverse, a common challenge is obtaining accurate, reliable, and cost-effective performance data that meets information needs.

The U.S. literature on building performance monitoring can be generally characterized as case study reports which emphasize the data and findings for a particular project. The results from these studies generally provide little potential benefit for other buildings because differences between buildings cloud comparisons. Protocols serve to promote comparability of projects, which can lead to increased knowledge by more practitioners.

In recent years field performance monitoring has developed into a specialized discipline, evidenced by the first National Workshop on Field Data Acquisition for Building and Equipment Energy Use Monitoring at Dallas, Texas, in October 1985. The proceedings from this workshop (including Hughes and Clark, 1986; Mazzucchi, 1986) provide an excellent overview of the state of field performance monitoring at that time, significant issues facing the monitoring community, and future directions. Field performance monitoring has been the subject of introspection and criticism by its practitioners. Recurring themes in this criticism include the need for detailed planning and the importance of establishing the relationship between the data collected and the objectives of the monitoring project (EPRI, 1983; Hughes and Clark, 1986). Project planning is often too hardware oriented, with insufficient emphasis on data analysis and development of data products that meet the project's goals and objectives. Monitoring projects have also been criticized for gathering excessive data for which there is no clear use. The development and use of protocols based on tested and accepted practices for planning and implementing field monitoring projects should help alleviate such shortcomings.

Protocols consist of experimental plans, specifications, and procedures for various field monitoring activities that are generally useful to others as models and examples of accepted practice. The focus is on methods and procedures for monitoring, as opposed to the selection and use of hardware. The areas of interest for the commercial monitoring protocol described here include field measurement of energy use, electric demand where possible, cost savings, and installation and operation costs of various energy efficiency improvements and procedures. Such field measurement implies a need to measure energy and power quantities for actual buildings and building systems and to record factors (such as weather, type of use, schedules, etc.) that affect energy use. However, monitoring projects are so diverse that no universal protocol can be expected to apply to all monitoring efforts, and the energy efficiency improvement focus of this protocol should be considered when forming ideas about what is presented.

In general, monitoring protocols are being advanced to serve as examples of good practice, to improve communication of the experimental design of specific projects, to achieve more uniformity in the development and documentation of monitoring projects, and to improve communication by use of a classification system. Protocols provide uniform guidelines and offer additional benefits if followed by a variety of different user groups. Field data are expensive to obtain and analysis expensive to perform, and such project results should be available to others for study or use with a reasonable level of effort for adaptation. Since guidelines are designed to ensure more consistent and comparable procedures, definitions, and data, those performing similar monitoring projects should be able to use other data sets with the knowledge that information collected is reasonably consistent and complete. Such exchanges of data will allow all involved to either increase their database or to collect only necessary (i.e., less) data.

BUILDING ENERGY MONITORING

Energy (and power) monitoring in buildings is conducted for a variety of purposes. Some of these are: utility planning, assessing the efficiency of building energy systems (new building performance, baseline performance, and evaluation of retrofits), systems development (heating-ventilating-air conditioning or HVAC, lighting, controls, etc.), tracking performance, assessing public policy, and diagnosing specific problems in buildings. Research efforts usually have a specific time frame associated with them, because they are often aimed at providing a period of relatively intense study to address specific types of analysis, planning, or policy issues.

Monitoring can aid the promotion of effective technologies by providing more reliable data on the expected benefits of energy efficiency improvements and demonstrating how improved monitoring and performance tracking methods help maintain efficient performance (long term benefits). This can stimulate more activity to achieve energy efficiency improvements. Thus, monitoring fits within an overall energy efficiency process by checking performance trends. Monitoring can also contribute to identifying potential energy performance problems in buildings and aid in identifying the options to pursue to improve energy performance. Monitoring is presently used by many professionals to guide improvements in building energy performance.

Energy monitoring can be intensive or basic. Intensive studies are those directed at understanding both what the measured energy performance is (the What?) and the root causes for observed energy performance (the Why?). Basic studies are directed at the "What question" of energy performance – how much energy was used or saved, although most studies will examine potential causes to some degree. Intensive studies tend to be more expensive, to include significant diagnostics testing, and to be studied and conducted over a shorter time. The EBER program is primarily interested in conducting basic monitoring studies initially, while explaining as much about the root causes of performance as possible with the available data.

Most monitoring studies can be identified as one of four general project types depending on the general goal of the study:

1. Whole Building Energy Use Monitoring

2. Energy End-Use Monitoring

3. Technology Assessments

4. Building or System Diagnostics

Whole building energy use monitoring studies generally analyze utility meter data for the whole building and generate energy and power use indices which can be compared across a group of buildings. Examples of analyses that might be performed include: using energy indices to identify those buildings which have a relatively large energy use and may be candidates for improvements, evaluations of conservation programs using data from many buildings, or using detailed hourly data to determine average power profiles for a group of buildings.

Energy end use monitoring studies for commercial buildings differ from whole building studies in that they require that energy flows and/or power levels in the building be measured in enough detail to provide breakdowns covering (typically) heating, cooling, lighting, fans, elevators, and "other," depending on the end uses of interest. The time frame of interest is often a year, to obtain seasonal data for the different end uses.

Technology assessments are directed toward measuring the actual field performance of a building system, retrofit measure, or other technology in individual buildings. The time frame of interest depends on the monitoring methods. This can be as short as two weeks or as long as a year. Characterization of the variations in performance for each building or system is usually of interest. Detailed supporting data such as laboratory performance information or on-site surveys are often part of the study.

Building or system diagnostics studies are generally short-term, with monitoring focused on answering specific questions related to energy use, power levels, or other performance parameters associated with specific buildings or building systems. Diagnostics testing (as opposed to diagnostics studies described in this paragraph) may also be part of other types of studies, such as systems technology assessments.

DEVELOPMENT OF PROTOCOLS

A procedure for uniform development and documentation of monitoring protocols has been proposed to improve communication and understanding of any particular protocol (Misuriello, 1987). The procedure includes the following major elements:

1. A classification system that broadly groups various types of monitoring projects and associated protocols based on similarities of goals, general approach, and data requirements (see the four categories discussed in the Introduction).

2. A guide specification which provides a consistent format for communicating the methodological requirements of protocols for particular monitoring projects. This format addresses procedures for stating the goals and objectives of the monitoring and research questions to be addressed, specification of data products, specification of data analysis procedures and algorithms, specification of data points to be monitored, special concerns of hardware selection, and procedures for quality control.

3. Standard terminology and definitions that further specify the monitoring protocol requirements. This includes definitions of measured quantities such as energy end-uses and published standards of measuring and testing procedures incorporated by reference.

RECENT EXAMPLES

There are relatively few references in the literature which specifically treat the methodological aspects of monitoring projects. With increased interest in methodological issues, technical papers on monitoring protocols are beginning to appear, published by the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) through its *Transactions*. Recently three monitoring protocols have been published which generally address the requirements described above.

A "Results-Oriented" methodology for field monitoring HVAC equipment (Hughes et al, 1987) is based on project experience at over 140 residential and commercial building sites. This protocol has been designed to yield reliable and accurate field performance data through close attention to quality control. It is intended to provide data for developing and verifying HVAC design and prediction models for technology assessment purposes. Its major application is for the assessment and subsequent commercialization and technology transfer of new or advanced technologies. The major contributions of this protocol include: its strong emphasis on project planning and quality control; advanced documentation and communications features through a uniform data acquisition and analysis (DAA) plan; its capability to collect non-metered data critical to meet project goals and objectives; and its procedures for the staffing and organization of technology assessment projects.

A protocol for utility load research (Mazzucchi, 1987) has been developed to collect data for the End-Use Load and Conservation Assessment Program (ELCAP), a large scale (~ 100 commercial building sites) monitoring effort conducted for the Bonneville Power Administration in the Pacific Northwest region of the United States. The data collected using the ELCAP protocol will be used to predict future electrical demands in the region and to develop methods to assess and acquire cost-effective building conservation resources. The unique aspects of this protocol include: a commercial sector sampling plan which addresses three strata of building sizes and ten building types; detailed procedures for developing site-specific measurement plans; and procedures to collect detailed building characteristics data. The significant contribution of the ELCAP measurement plan has been in the area of standard terminology and definitions. This measurement plan defines twenty specific energy end-use categories along with identifying codes for associating commercial building equipment with end-uses. Identifying codes for building functional space use types are also included in the protocol. This approach greatly increases data collection consistency, since data definition errors are minimized.

A protocol for single-family building retrofit performance (Ternes, 1987) was developed by DOE to answer specific research questions associated with the actual measured performance of residential retrofits. Discrepancies between predicted and actual retrofit performance are common. This protocol recommends a "before and after" experimental design approach, and specifies a minimum data set to be collected to determine actual retrofit performance on a "normalized" basis as defined in the literature (Fracastoro and Lyberg, 1983). The basic parameter data set includes time-series data for heating or cooling consumption or both, total consumption by fuel type, and indoor temperature. The protocol allows both hourly and weekly recording intervals for time-integrated parameters. It also includes data collected on a one-time basis such as: house and space conditioning system descriptive information, beginning and exit occupant interviews, infiltration measurements, and assessments of retrofit installation quality. Optional data parameter sets are included in the protocol for users who wish more analytical information. This protocol's contribution has been to standardize the experimental design and data collection specifications so that independent researchers and projects obtain comparable results. The approach of both minimum and optional data sets and two recording intervals accommodates research projects of varying financial resources.

THE COMMERCIAL MONITORING PROTOCOL

STRATEGY

The strategy used for this protocol is to specify basic data requirements for describing the measured field performance of efficiency improvements in buildings. The requirements cover description of a project or program, description of the analysis and reporting of specific analysis results, minimum requirements for measured data, and description of the building or buildings that were monitored through use of a building description data set. Sharing the cost of field monitoring projects with other groups or associations having similar interests has been and is expected to continue to be an important part of the EBER program. Since data are expected to be collected by different investigators, the protocol helps to ensure that data from projects are reasonably consistent and comparable.

These data requirements are directed at improving the understanding of energy efficiency improvements, and in the long run, learning how to simplify the data needed. Improved understanding is meant to increase the ability of energy professionals to communicate with one another, with clients, and possibly with regulators about how building energy performance has been and could be improved.

DESCRIPTION OF REPORTING REQUIREMENTS

The requirements for reporting data include four general categories:

- Project or Program Description – general information including identification of the project or program, why it was conducted, and what improvements were made to the buildings or systems studied
- Analysis Methods and Results – summary of analysis (evaluation) methods, experimental design, and project results
- Performance Data – summary of monthly (billing) data, submetered or detailed energy consumptions, inclusion of demand data (if any), and temperature and weather data
- Building Description Data – survey data which describe each building and associated building systems, functional use areas, tenants, schedules, base energy data, and energy improvements

Additional requirements are also suggested for transfer of data results using computer media. These suggested requirements are described only on the Data Transfer Form in **Appendix D.** The Data Transfer Form should be completed only when data are to be transmitted to another person or organization, and mutual agreement should determine what parts of the Data Transfer Form are to be completed.

The forms used to provide the required data are also contained in **Appendix D.** Instructions for completing the forms for the required data are provided in this section for all forms except the Building Description Data Forms. Although a general description of the requirements for the Building Description Data Forms is provided in this section, the detailed instructions are provided in **Appendix A.**

Project Description

The following information should be reported as overall project description requirements (use the Project Description Form, **Appendix D**):

1. Project or program identification, sponsoring organization(s), and contact persons for anyone interested in learning more about the work

2. Number of buildings involved in the project and a brief description of the types of buildings

3. The project goals, objectives, and/or research questions addressed

4. A brief, general description of the energy improvements made to the building(s) or system(s) during the project (shell retrofit, systems retrofit, O&M change, other)

Discussion on the Project Description Form is needed only to the extent necessary to explain project motivations, desired results, and changes that were made during the monitoring that would affect energy use.

Analysis Methods and Results

The Analysis Methods and Results Summary Form is used to document the general design and approach used for the project to obtain and analyze results. The experimental design is recorded (Fracastoro and Lyberg, 1983; Ternes, 1987). Many different types of experimental designs can be found in the research literature on studies of energy efficiency in buildings, but most can be characterized as using one or more of the following general experimental design classifications:

1) **On-Off.** If the efficiency improvement can be turned "on" and "off" so that the efficiency impacts can be seen in the "on" period" and not in the "off" period, this is a good way to observe the benefits of the improvement. The on-period impacts are compared to the off-period impacts.

2) **Before-After.** Energy efficiency in a building before improvement of interest is compared to that after installation. Accounting for changes in the weather and building operation in the two periods is usually essential, mandating a model-based analysis.

3) **Test-Reference.** Energy consumption in the building with the improvement is compared to an otherwise "identical" building. Because "identical" buildings cannot be achieved in practice (different crack distributions, insulation effectiveness, temperature settings, solar exposure, etc.), a calibration period relating the two buildings before installation is necessary. The improvement is installed, and the deviation from the calibration relationship is attributed to the product.

4) **Simulated Occupancy.** This design is sometimes used for studies of residential buildings to reduce "noise" in energy use patterns caused by occupant effects. Use of this design for commercial buildings is seldom practical except for short periods to examine portions of the energy use pattern impacts of equipment, occupants, or systems.

5) **Non-Experimental Reference.** A reference for assessing the performance of a building can be derived "non-experimentally" by: 1) using a normalized, stratified performance database (e.g., energy use per square foot by some building type classification) (MacDonald and Wasserman, 1989), or 2) by using a "reasonable" standard building simulated by a calibrated simulation model subject to the same weather and occupancy as the monitored building.

6) **Engineering Field Test.** When the experiment is focused on the performance of a particular piece of equipment, the total building performance is not of primary interest. The building provides a realistic environment for the testing of the equipment, where reliability, maintenance, comfort, noise, etc. may be considered in addition to energy. Measurements of the impacts of the equipment on efficiency are made, and the whole-building energy impacts are derived using one of the above approaches. The equipment may be extensively instrumented.

The approach used for analyzing building or system energy performance is described by recording the level of data detail, the type of modeling used for the energy data, and the form or type of the model (or equations) used to describe building or system performance. Any calculations or methods used to account for performance variations caused by changes in building characteristics (if any) are also recorded.

The Analysis Methods and Results Summary Form is also used to record the basic analysis results for the energy improvements that were installed. Results must include both energy and cost savings (including demand savings for electricity, if applicable). The annual energy use intensity (EUI, kBtu/ft^2) before and after the improvement must be calculated and recorded for heating, cooling, and the whole building if applicable to the energy improvement. For improvements affecting heating and/or cooling, the annual building performance index (BPI, kBtu/ft^2/DD, where DD refers to heating degree days or cooling degree days as appropriate) should be calculated and recorded. Any other performance index important to interpreting the results should also be recorded. Typical electric demand values are entered as appropriate and available (enter NA if not applicable or available) for the summer, winter, or other period of importance before and after the improvement is installed. The effects of complicated demand price structures may cause difficulties in presenting useful values, so choose what seems to be the most appropriate and describe important features of demand effects elsewhere on the form.

Cost savings are entered on the form and must indicate the breakdown between energy cost savings, demand (power) cost savings, and operation and maintenance (O&M) cost savings (as known). A description is entered of the overall project results in simple terms, which should include a brief explanation of how energy, demand, and O&M cost savings were estimated and of the effects of weather and other normalizations on the results. Confidence in the results (energy and cost savings and implementation and O&M costs) should be reported if possible. Confidence can be either a statistical determinant or a qualitative description.

The costs for implementing the efficiency improvement, and any (known) increased costs resulting from the improvement, such as increased electric demand or O&M costs must also be reported. Together with the cost savings, the costs for implementation (and any increases in other costs) should be used to report measures of cost effectiveness. The basis for the cost effectiveness values and the expected life of the improvement should be reported.

Finally, any important changes in amenities such as comfort, lighting quality, or noise reduction that are important in reviewing project results may be reported. Information is not required here and reporting in this category is optional.

Performance Data

The objectives and resources of different projects normally influence the amount and detail of monitored data. This protocol requests data at two levels of detail: monthly (billing) and at a more detailed field recording interval(s). The billing data are required as a minimum, but submetered data are often necessary to provide more meaningful results. Submetered data include data for one fuel or for end uses such as cooling or lighting at recording intervals shorter than one month.

Since monitoring at short time intervals can easily produce large amounts of data, the maximum amount of submetered data that should be supplied is for aggregated major (at least 10% of total) end uses (or total fuel use) for 12 months before and after an efficiency improvement is installed. Performance data required for this protocol are outlined in Table 1 for projects with and without submetered data.

Table 1. Performance Data Requirements

PROJECTS WITH SUBMETERING

	Before Retrofit	After Retrofit
UTILITY BILLING DATA [REQUIRED] (provide for each fuel)	12 months minimum	3 months minimum (optional update to 12 months)
SUBMETERED DATA (maximum allowed for all recording intervals)	All data for each major end use up to 12 months	All data for each major end use up to 12 months

	Type	Recording Interval	Period Length
TEMPERATURE DATA (daily max. & min. must be provided for any periods without integrated averages)	Max. & min. — or — Integrated averages	Daily — or — Same as for submetered data but not longer than daily	Same as billing data length — or — Length of submetering

PROJECTS WITHOUT SUBMETERING

	Before Retrofit	After Retrofit
UTILITY BILLING DATA (provide for each fuel)	12 months minimum	12 months minimum

	Type	Recording Interval	Period Length
TEMPERATURE DATA	Max. & min. — or — Integrated averages	Daily	Same as billing data length

Data that are supplied should be consecutive in time for each of the pre- and post-retrofit periods with as few gaps as possible (preferably none). This helps ensure that conditions outside of those affected by the retrofit either can be detected in the data stream or remain as constant as possible, e.g., no changes in occupancy, operating schedules, operating modes (heating to cooling or vice versa), building use, or other variables. If these conditions could all be held constant, then a change in energy use would be a result of the retrofit only.

Minimum Data Sets. For projects without submetering, the minimum set of performance data that will satisfy this protocol consists of energy billing data for each fuel used in a building together with daily outdoor temperature data. Billing data must be provided for 12 months before and 12 months after an energy improvement. For projects with submetering, the minimum data set includes the billing and temperature data along with the submetered data up to a 12-month maximum. For submetering projects, the 12 months of billing data after the improvement can be supplied in two parts, permitting an experimenter to begin providing data soon after the energy improvement has taken place.

Billing Data. Summaries compiled from individual bills are satisfactory to meet the billing data requirements. However, billing summaries as supplied by the appropriate utility are preferred. If multiple fuels are used in a building, billing data for each fuel should be reported. Electric demand billing data should be reported when available. A common complication associated with billing data is that the ending dates of billing periods and the dates of billings (when billed) are often difficult to distinguish on utility summaries. Care should be taken to ensure that the dates supplied with billing data correspond to the actual dates of meter readings.

Submetered or Detailed Data. Submetered or detailed data should be provided as available up to the 12-month maximum. For any studies dealing with whole-building impacts, data can be provided for individual fuels or at the end use level. However, end use levels should not be more detailed than for major end uses, where major end uses are considered to make up at least 10% of the annual energy bill for the building and typically are lighting, space heating, space cooling, water heating, and "other" uses. The sum of major end uses plus the "other" end use should approximately equal the total building energy use. For studies dealing with impacts of individual systems, submetered or detailed data do not have to encompass the entire end use. However, studies of individual systems should report the expected impacts on total building energy use on the Analysis Methods and Results Summary Form.

Temperature and Weather Data. Outdoor temperature data should be supplied on a daily basis as a minimum. Shorter interval temperatures are acceptable, i.e., hourly, 15-minute, etc. Daily outdoor temperature data should be provided as daily maximum and minimum temperatures (two values) or as integrated averages. Additional weather data may be provided as appropriate and as available (e.g., insolation data will likely be recorded for daylighting or window film improvements). Supplied weather data should of course correspond to periods over which energy use data (billed and submetered) are provided.

Building Description Data

Building description data must describe both the "before-improvement" and "after-improvement" conditions (two distinct conditions). The Description Data Forms should be completed entirely for the before condition. This can be done at the time of the initial building survey or audit. The after condition can be documented by describing the changes together with the before condition (see Appendix C) or by using a new set of Description Data Forms to describe the "after" condition. The Building ID block (Building ID, Before/After condition, and Date) should be completed for any Description Data Form used. If a new set of forms are used for the after condition, entries should be made on the forms only where changes have occurred. In most cases the after condition can be described using the same set of forms used for the before condition, or if separate forms are used, only one or two partially completed pages of the description data forms will be necessary to document the after condition. When two sets of forms are used, uncompleted parts of the description data forms for the after condition will be assumed to indicate that the same conditions apply to the building before and after for that part of the forms.

Detailed instructions for completing Building Description Data Forms are in Appendix A. Description data forms should be completed by someone with experience in buildings energy use and a significant knowledge of building energy systems. The building description data cover building characteristics and a description of energy improvements that have been made to each building or system. The building description data are divided into seven categories:

- General data and building envelope
- Building zone information
- Systems data
- Energy improvements being evaluated
- Tenant information
- Zone schedule and occupancy
- Monthly energy and fuel

General building data identify the building type and age along with building size data. In addition, above and below ground areas are described. General building data also requires information on envelope boundaries. Envelope data describe envelope areas and constructions, which includes coding to identify construction details of above- and below-grade walls, the roof, floor, doors, and windows. Wall and glazing areas are related to their orientations, and the predominant opaque wall conductance (U-value, Btu/h-ft^2-F) must be estimated.

Tenant and zonal data are required to separate the building into respective tenant and zonal areas. The building is first divided into tenant areas and then into functional use zones for each tenant. Thus, the zone is the smallest area described. Basic sizes of each tenant area and each zone are documented along with other characteristics unique to the zone and tenant. These characteristics include zonal temperature setpoints and whether the tenant pays the utilities. Standard Industrial Classification (SIC) codes (from Appendix B) are recorded for each tenant to provide later linkage with planning or evaluation models or tools (such as utility power forecasting models). Information as to whether each tenant is an owner or lessee is also documented. Schedule and occupancy data are recorded for each building tenant zone for all seven days of the week and holidays.

Systems data focus on the major energy-using systems within the building, including HVAC and lighting. HVAC and lighting systems are related to the appropriate tenant/zonal areas served. The heating and cooling capacities and configurations and fuel types of HVAC systems are recorded. Controls information is provided for each system.

Lighting systems data identify the types of lighting units, the number of units in the building, and the power of each unit. Operational schedules of lighting systems are used to describe how lighting is used in the building during both occupied and unoccupied periods. Controls information is also needed for each lighting system.

The energy and fuel requirements identify each fuel or energy supplier, the fuel type, the system IDs of the systems receiving energy from each fuel, and the number of meters for each fuel.

The final building description data requirement is a description of completed energy improvements being evaluated. This description includes identifying the system types affected and relating the energy improvements to the affected tenants and zones. Other details of the energy improvements include installation periods and costs. The annual savings for the energy improvement estimated prior to installation is also requested.

FOLLOW-UP REPORTING

Follow-up reporting and tracking of improved energy performance is encouraged. Updates can be used to indicate continued progress on improving energy performance and whether changes in building use or O&M are affecting energy performance. Long-term performance records are presently used to document continuing progress at some large facilities, and this type of record is needed for other buildings. Follow up reporting does not necessarily have to be continuous, but some type of update can be used in verifying long-term performance. The same forms can be used for updates. Only entries for those parameters/characteristics that have changed must be entered. The identifying information at the top of page 1 of the Building Description Data Form must be included.

JUSTIFICATION OF DATA PARAMETERS

The Commercial Monitoring Protocol defines basic data needed to describe a commercial or related building and provide building energy use data before and after a retrofit improvement is installed. The protocol also requires that analysis methods and results be presented briefly. Data requirements of this protocol can be divided into point-in-time information and time-dependent information. The point-in-time information describes the building that is monitored in the "before" and "after" conditions (before and after an energy improvement is installed and monitored). Time-dependent data change continuously with time, e.g., energy consumptions and outdoor temperatures.

POINT-IN-TIME INFORMATION

The point-in-time information required by this protocol is for the building description data, which is recorded under the seven categories discussed in the previous section of this document.

The General Building data are used to group similar buildings to study building distributions. In addition, data will be used to normalize energy use, savings results, and other parameters of interest so that building to building comparisons and averages can be generated.

Envelope data are used to provide information on both the surface areas of a building and its construction. Envelope constructions are primarily used to approximate the average heat transfer characteristics of the envelope. Glazing areas also provide heat transfer information, and orientation and shading data provide additional indications of solar contributions to building loads.

It is common for both large and small buildings to have multiple tenants. Multiple tenants often require building zoning such that each tenant can be separately responsible for their energy needs. Thus, multiple utility meters may exist for a single building. Separate systems (particularly HVAC) are also common for multiple tenancy. Also, different tenant/zone areas may have higher or lower intensities of energy use. Since energy improvements in a building may not necessarily affect all tenants, zones, and systems, Tenant and Building Zone data are needed to clarify building configurations.

Zone Schedule and Occupancy data summarize the operating schedule and the average occupancy levels of building zones. The operating hours and the occupancy level have been shown to be significant indicators of energy use (Haberl and Claridge, 1987). As a result, these data can be crucial in making comparisons of energy use between buildings.

Systems data identify the major energy-using systems and their operational controls. Since controls often have a major impact on relative energy efficiency and are an attractive area for energy improvements, it is necessary to know the equipment and general types of controls that exist. Equipment capacities can indicate sizing problems for a building, and they can often identify operational changes that can lead to significant savings. Since systems are often devoted to specific areas of a building, relating systems to tenant and zonal areas is also needed.

Data on the utility and/or fuel supplier are used to check against the Monthly Energy and Fuel data provided for each building. Data on the number of meters are used to clarify whether all required data have been received.

Data on the Energy Improvements Being Evaluated are used to categorize energy improvements and the systems affected. Cost and savings data will be used in future statistical treatment of the cost-effectiveness of the improvements.

In summary, the information on the Building Description Data Form will be used to develop categories for analyzing and understanding energy performance and improvements. While there are potential problems related to the complicated nature of buildings, their uses, and systems and to the qualitative nature of some of the information requested, these data will provide the basis for initial analytical studies. Categories of building energy use and performance will be developed to allow comparison and ranking of power and energy use patterns to better understand efficiency improvements in different building types.

TIME-SEQUENTIAL INFORMATION

The time-sequential data required per this protocol are summarized on the Performance Data Requirements Form. Time-sequential data are divided into three categories:

- Billing Data
- Submetered or Detailed Data
- Temperature and Weather Data

As monthly consumptions are highly aggregated totals, they mask shorter-term energy use excursions and limit the types of analysis that can be performed. However, monthly billing data can be used to examine major dependencies of building energy use and are always needed as an aggregated determinant of energy use. The degree to which monthly data can be used to characterize energy use is largely dependent upon each individual building. Monthly data can also be used for comparisons between buildings through the use of average annual energy use intensities and monthly power densities (MacDonald, 1988).

Submetered or detailed data are normally obtained through site monitoring at either weekly, daily, hourly, or 15-minute intervals, typically. Depending on the recording interval, these data can support different potential building energy analyses. These data can provide insight concerning effects on selected energy end-uses, demand profiles, equipment evaluations and diagnostics, occupancy effects, and numerous other effects, most of which cannot be disaggregated using billing data.

Outdoor temperature is normally a primary indicator of the energy needs of a building. Thus, it is a necessary parameter in most if not all building energy-use modeling. Since buildings often experience different weather conditions before and after a retrofit, it is necessary to compensate for variations in outdoor temperature. Comparisons between buildings from different locations also usually require temperature compensation. Temperatures recorded on a daily basis are most frequently used and are often the most useful for analysis. Daily maximum and minimum outdoor temperatures are part of the widely-used, variable-base heating degree day methods for modeling energy use.

THE MINIMUM DATA SET

All data sets generated using this protocol require the following:

- Project Description Form
- Building Description Data Forms
- Performance Data Requirements Form
- Analysis Methods and Results Summary Form

While the Project Description, Building Description, and Analysis Methods and Results forms should be completed similarly for all projects, the Performance Data Requirements Form can be completed at a minimum level. The minimum performance data required per this protocol are billing data along with corresponding outdoor temperature data. An additional form, the Data Transfer Form is used only when sending data from one person or organization to another.

Although the minimum data set only requires monthly data to be reported, users of this protocol should strongly consider the need for submetered data to provide useful measurement of the efficiency impacts of interest for many projects. In many cases utility billing data will not provide enough information to differentiate efficiency changes from other energy use changes (such as increases in use of electrical equipment).

The minimum data set was selected in order to obtain as much information about a building and its performance as possible while maximizing the number of projects that could participate. By selecting readily-available billing and outdoor temperature data as minimum performance data requirements, the numerous buildings where energy improvements have been made without submetering are also eligible to provide data using this protocol.

RECOMMENDATIONS

This monitoring protocol serves as a model for data collection and documentation of basic project details and results. Widespread use will promote uniformity in the data collected as part of verifying energy use improvements. Adopting a standard data collection format will provide comparability and thus will be a key step in maximizing the returns from independent studies of energy improvements.

We recommend that the EBER program begin using this protocol for studies of energy efficiency improvements in commercial and related buildings. We expect that data collected under this protocol will provide useful information for the Building Energy Compilation and Analysis data base for commercial retrofits (BECA-CR) maintained at Lawrence Berkeley Laboratory. After initial data collection activities, significant analysis of the benefits of this protocol for monitoring the performance of energy efficiency improvements is needed.

We recommend that submetered – or more detailed than monthly – energy use data be provided for most projects. More detail is desirable since typical billing data (recorded monthly) do not permit discernment of many of the driving factors which influence energy use and reduce the level of differentiation between efficiency benefits and other causes of energy use changes ("noise"). In addition, many months may be required to collect enough data to achieve desired confidence levels for results (Ternes, 1987).

Certain quality tests are needed to evaluate the usefulness of the information required under this protocol. It is likely that field procedures will need to be developed to handle difficulties that arise in interpreting the information needed for the forms. The qualifications needed for field personnel should also be determined through field tests. Cross checks of variations in data collection results for specific buildings should be conducted to evaluate the potential impact of field data collection personnel on the results achieved. This should be accomplished by having different "teams" provide the data independently.

Improved usefulness of results using this protocol is expected if buildings are evaluated by specific region or climate, instead of developing national aggregations. This is because climate, and associated regional differences in building construction and energy systems used, introduce significant variation in energy use and potential energy savings for energy improvements (McLain et al, 1988). National aggregations of savings for particular types of retrofits will have this additional confounding effect present in reported results.

Significant development of analysis techniques is still needed to support studies of energy efficiency in commercial buildings. The issue of recommended techniques must be evaluated further as testing of the proposed methods continues (MacDonald and Wasserman, 1989).

We have attempted to balance the need for information with the need to keep a simple, workable scheme for data collection. The approach presented in this document should be used as the starting guide for field trials.

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Appendix A

INSTRUCTIONS for
Building Description Data Forms

INSTRUCTIONS for Building Description Data Forms

PRELIMINARY INFORMATION

Prepared by: The name of the individual completing the form.

Building ID: [Enter on each page] An identifier unique for each set of forms indicating the building surveyed. The fundamental unit of analysis is the building. Each building can be described by identifying "tenants" who carry on specific business activities described by the SIC codes (Appendix B). If a building has several wings served by different mechanical systems and utility meters, they could be identified as separate buildings. A separate set of survey data forms should be filled out for each "building."

Before condition/After: [Enter on each page] Indicate with a check in the appropriate space whether the information provided is applicable to the building before or after the energy improvements, or both.

Date: [Enter on each page] The date the form was entered. An update to the forms will be identified by a later date but identical Building ID and Project/program ID.

Building location: General location of the building, not the mailing address. If "city" designation is not applicable, give other identifying information, such as township. The zip code should correspond to mailing addresses in the physical location of the building.

Project/program ID: Distinguishing identifier of the project or program dictating the need for the data. Identical to the corresponding entry on the Project Description Form.

1. GENERAL DATA AND BUILDING ENVELOPE

Age category: Indicates the approximate year construction was completed on the building surveyed (excluding any additions to be described below).

BECA building type code: Indicates the major use of the building using the "Buildings Energy-Use Compilation and Analysis" (BECA) codes as shown on the form.

Total Floor Area: Floor area of all spaces, conditioned and unconditioned, considered as part of the building surveyed. Include the areas of all additions completed at the time of the survey. Consider all stories, not simply the "footprint" area.

Year of latest renovation: Year of completion for any renovation of more than 30% of the existing building. Do not consider additions themselves as renovations. They will be listed below.

Floor area of latest additions: Total floor area added to basic structure since year indicated in "Age category." Year completed: Give the year of completion for each corresponding addition listed in the previous line.

Number of stories: General indication of the height of the building. Include all levels, both above and below grade, considered as part of the building surveyed. Fractional entries should be explained.

Floor area and volume: Enter the total area and volume of space that is heated, cooled, and unconditioned for above and below grade levels. Atria are entered separately and should not be included in the totals entered previously. Areas both heated and cooled will be recorded twice.

Stories above ground: The number of stories above grade. Fractional entries should be explained.

Roof pitch: The average or predominant roof pitch. Exposed roof area: Area of the top surface covering the structure surveyed and exposed to outdoor conditions. If surveyed structure consists of the central floors of a multi-floor building, this area may be zero. Roof insulated at: (self explanatory).

Roof and wall U-values: Enter the best estimate of these values to indicate the average over the total roof area and over the total opaque wall area.

Ground-coupled floor area: Floor area having thermal contact with the ground primarily by conduction (e.g. a concrete slab). The ground-coupled floor area would be zero for a floor separated from the ground by a crawl space.

Common walls: The percent of envelope walls surrounding the surveyed structure which are adjacent to conditioned spaces not considered in the survey. If only one store in a strip shopping plaza is being surveyed, it may have greater than 50% of its wall area common to other conditioned spaces.

Building shell construction codes: Enter the codes from the selection given indicative of the predominant construction type for each of the designated components of the building. Describe in the "Description of variances" section any major distinguishing features of a construction which would affect energy consumption yet not apparent from the titles given in the listing. Also explain any use of the "O - Other" category.

Walls and Glazing: Enter the percent of total glazing area attributed to the predominant and secondary major window types. Enter the estimated glazing U-values and circle the items applicable in describing the glazing and sashes of the two window types. Indicate whether each window type is fixed or operable (capable of being opened). Use the tabular spaces to divide the above grade gross building wall area--which includes glazing area--and the glazing area by orientation. Indicate whether the glazing on each face is shaded by overhangs or fins and whether any photographs of the building faces are included with the survey data. Mark them by orientation if included. Use the "Description of variances" section at the bottom of the page for any explanations, limitations, or major features not covered in the preceding description.

Maintenance: Enter the percentage of HVAC maintenance costs supplied by the indicated methods:

- In-house – performed by dedicated maintenance staff employed by the building tenants
- Continuous contract – performed under a contract entered into prior to the actual need for specific maintenance and applicable for a specified period of time
- Contracted as needed – performed under contract entered into as need for specific repairs arise, applicable only to individual repairs.
- Owner/tenant – performed by the tenant personally
- Other – describe in the "Description of variances" section.

Description of variances: Clarifications, limitations, uncertainties, or other explanatory information for any entries on the first page.

2. TENANT INFORMATION

Tenancy: Indicate the percentage of total building floor area leased and the percentage occupied by the building owner. If "other" is indicated, clarify in the "Description of variances" below.

Tenant table: For each individual tenant assign a unique tenant number and name, for ease in identifying the occupant. Common areas leased to no tenant--such as lobbies, cafeterias, and corridors--should be assigned tenant number 0 with "Common" as the tenant name. For each tenant, list the total floor area occupied, the SIC code from Appendix B which best describes the major business activity of the tenant, and whether the tenant is responsible for paying their own utilities. The use of the SIC codes may cause difficulties in some cases, and if users have difficulty the nature of the business should be described below the table. Industrial buildings are a special case where the SIC code should not be entered. The BECA code should be entered again, and the type of industry or nature of the products made should be described below the table. At the bottom, sum the individual areas to show the total floor area. Any differences between this total and the totals for Part 1, General Data and Building Envelope should be explained.

3. BUILDING ZONE INFORMATION

Subdivide the space occupied by each tenant into zones, each representing a different major functional use. A major functional use is one which requires more than 10% of the total building floor space. Assign a tenant/zone number consisting of the tenant number followed by a letter, beginning with "a," increasing consecutively, covering all major uses for each tenant (e.g. 1a, 1b, 2a, ...). Identify the major functional use of each tenant/zone through entry of the "Use Code" selected from the values listed under "Additional Codes" at the conclusion of the forms. Enter the floor area and predominant ceiling height for each tenant/zone and the occupied and unoccupied thermostat setpoints most frequently used in the zones. Describe any variances.

4. SCHEDULE AND OCCUPANCY

List the normal working hours (00:00 to 23:59) by day of the week for each tenant/zone number identified in the previous table. The average occupancy level should be expressed in occupant-hours. For example, 1 occup.-hr. = one occupant for 1 entire hour or 4 occupants for 15 minutes. Where occupancy is variable, occupant-hours can be calculated as in the following example:

A business operates 9 hours per day. The building has 12 steady occupants during business hours (e.g. salespeople) plus approximately 300 customers per day averaging 10 minutes in the building per customer. The average occupancy level is:

Occupancy = [12 occup. x 9 hrs. + 300 occup. x (10/60) hrs.] = 158 occupant-hours.

The occupancy during non-business hours may be disregarded unless substantial when compared to the business hours occupancy. Identify tenant/zone numbers of those zones with no set schedule of occupancy and other variances on the line following the table.

5. SYSTEMS

HVAC systems: Use the table provided to describe each HVAC system and the tenant/zones served by the system. For each system, indicate an HVAC type code from the list to the right of the table and select a means of control indicating how the system is activated or deactivated. HVAC systems are separated into two categories: packaged or secondary systems (Pkg/Scndy on the form) and primary systems. If all the HVAC equipment is packaged (or self-contained unitary) equipment, with no primary boilers or chillers (or other primary equipment), the primary systems portion of the form will have no entries. If a primary system provides heated or cooled fluids to secondary systems, e.g., fan coil units throughout a building supplied by a central hot water boiler, both the primary and secondary systems should be described.

For the controls codes, enter the type of control system for heating, cooling, or both (e.g., b-3 for a regular thermostat controlling both heating and cooling). The "smart" thermostat control allows programming of zonal setpoints by time of day. EMCS indicates control with an Energy Management and Control System. List which tenant/zones each system serves. A single system may serve multiple zones or a single zone may be served by more than one system. Give the system cooling and heating capacities under peak conditions (e.g., with the design chilled water temperature and flow rate). Indicate if the system is a packaged unit or a secondary system, whose primary source of conditioning fluid is a central unit or plant. Systems may be both packaged and secondary (p + s) if, for example, their cooling is localized but their heating media is provided by a central source, such as a central hot water boiler. For packaged units, specify a fuel type code(s) in conjunction with its packaged designation, e.g. "p, eg" for a packaged unit having electric air conditioning and a gas furnace.

Primary systems: Describe in the table provided characteristics of any primary system supplying hot or cold fluids to any of the secondary systems listed in the previous table. Choose a system type and energy source from the list provided. Enter the estimated total input and output capacities of the central plant, the operating power of the associated pumps, and which of the secondary systems listed previously are served by the primary system.

Description of variances: Describe any variances or explanations that will better clarify heating and cooling systems, especially those where both packaged and secondary entries have been made.

Lighting: For each tenant/zone surveyed, or groups of zones having similar lighting, enter the tenant/zone number(s), the lighting code from the list provided which describes the lighting type and the wattage of each unit. Indicate the total number of units in the tenant/zone(s) and the number of units out of the total that are not working, inoperable or generally not used. One entry should be made for each lighting type and size (watts/unit, including any ballast power) in each zone. (Use an additional sheet if necessary.) The percent on values for occupied and unoccupied periods should indicate a value that provides an estimate of electric lighting consumption when multiplied by the total power of working lighting units.

If the lights for a major tenant/zone are on no specific schedule, such as those in a conference center used only at irregular intervals, make the best estimate of percent on and indicate difficulties under the "Description of variances." Enter the mechanism controlling the lights from the list provided. If "Other" is chosen, explain in the "Description of variances" section which follows.

Other Major Energy Consuming Systems: For any tenant/zone having major energy consuming equipment not specified previously, such as computer facilities, refrigeration equipment, etc, provide a System ID and list the tenant/zone. Use the type codes provided to describe the apparatus. Enter the fuel code, selected from the listing in the "Primary HVAC Systems" section, which supplies power to the equipment and the connected power or capacity (kW) for the equipment.

6. MONTHLY ENERGY AND FUEL

Enter information pertaining to the utility/fuel statements which are attached to the survey forms. Give the name of the energy supplier and the type of fuel from the list in the "Primary HVAC Systems" section. Enter the System ID numbers of the supplied HVAC systems and the number of meters monitoring the fuel use.

7. ENERGY IMPROVEMENTS BEING EVALUATED

Describe the specific energy improvements being evaluated. Use the Energy Improvement Codes described on page 6 of the forms. Enter two to three words to describe the improvement being made and the tenant/zone numbers of those zones whose energy consumptions are affected by the measure. If the measure affects the operation of an entire HVAC system, enter the applicable System ID number. For improvements not reasonably defined by the codes (esp. those ending with 'X' or 'Z'), describe the energy improvement more fully in the "Description of variances" section or with an attachment. Enter the time period required to install the measure, the total cost of the installation, and the estimated annual savings produced by the energy improvement, both in thousands of dollars. Any other additional explanations may be entered in the "Description of variances section."

Appendix B

Standard Industrial Classification Codes

This appendix lists the Standard Industrial Classification (SIC) codes used to classify the activities of tenants. The abbreviation "nec" means "not elsewhere classified."

This listing uses the "short" SIC titles from the *Standard Industrial Classification Manual* issued periodically by the Office of Management and Budget, Executive Office of the President of the United States.

This listing was originally developed by Pacific Northwest Laboratories (Mazzucchi, 1987) under the End-Use Load and Conservation (Consumer) Assessment Program of the Bonneville Power Authority.

WAREHOUSES

Short Title	SIC Code
Local trucking and storage	4214
Farm product warehousing and storage	4221
Refrigerated warehousing	4222
Household goods warehousing	4224
General warehousing and storage	4225
Special warehousing and storage, nec	4226
Trucking terminal facilities	4231
Wholesale trade - durable goods	5000
Printing and writing paper	5111
Stationery supplies	5112
Industrial and personal service paper	5113
Drugs, proprietaries, and sundries	5122
Piece goods	5133
Notions and other dry goods	5134
Men	5136
Women	5137
Footwear	5139
Groceries, general line	5141
Frozen foods	5142
Dairy products	5143
Poultry and poultry products	5144
Confectionery	5145
Fish and seafood	5146
Meats and meat products	5147
Fresh fruits and vegetables	5148
Groceries and related products, nec	5149
Cotton	5152
Grain	5153
Livestock	5154
Farm-product raw materials, nec	5159
Chemicals and allied products	5161
Petroleum bulk stations and terminals	5171
Petroleum products, nec	5172
Beer and ale	5181
Wines and distilled beverages	5182
Farm supplies	5191
Tobacco and tobacco products	5194
Paints, varnishes, and supplies	5198

DRY GOODS RETAIL

Short Title	SIC Code
Nondurable goods, nec	5199
Building mat. and garden supplies	5200
General merchandise stores	5300
Candy, nut and confectionery stores	5441
Retail bakeries - selling only	5463
New and used car dealers	5511
Used car dealers	5521
Auto and home supply stores	5531
Boat dealers	5551
Recreation and utility trailer dlr.	5561
Motorcycle dealers	5571
Automotive dealers, nec	5599
Apparel and accessory stores	5600
Furniture and home furnishings	5700
Miscellaneous retail	5900
Photographic studios, portrait	7221
Beauty shops	7231
Barber shops	7241
Shoe repair and hat cleaning	7251
Blueprinting and photocopying	7332
Equipment rental and leasing	7394
Miscellaneous repair services	7600

GROCERIES

Short Title	SIC Code
Grocery stores	5411
Meat and fish (seafood) markets	5423
Dairy products store	5451

RESTAURANTS

Short Title	SIC Code
Eating and drinking places	5800

OFFICES

Short Title	SIC Code
Freight forwarding	4712
Passenger transportation arrang.	4722
Freight transp. arrangement	4723
Banking	6000
Credit agencies other than banks	6100
Security, commodity brokers and serv.	6200
Insurance carriers	6300
Insurance agents, brokers and serv.	6400
Real estate operators and lessors	6510
Non-residential building operators	6512
Lessors and railroad property	6517
Real property lessors, nec	6519
Real estate agents and managers	6531
Title abstract offices	6541
Subdividers and developers, nec	6552
Cemetery subdividers and developers	6553
Combined real estate, insurance, etc.	6600
Holding and other investment offices	6700
Advertising agencies	7311
Outdoor advertising services	7312
Radio, TV, publisher representatives	7313
Advertising, nec	7319
Credit reporting and collection	7321
Direct mail advertising services	7331
Commercial photography and art	7333
Stenographic and reproduction, nec	7339
Window cleaning	7341

OFFICES (cont'd)

Short Title	SIC Code
Disinfecting and exterminating	7342
Building maintenance services, nec	7349
News syndicates	7351
Employment agencies	7361
Temporary help supply services	7362
Personnel supply services, nec	7369
Computer programming and software	7372
Data processing services	7374
Computer related services, nec	7379
Management and public relations	7392
Detective and protective services	7393
Trading stamp services	7396
Business services, nec	7399
Offices of physicians	8011
Offices of dentists	8021
Offices of osteopathic physicians	8031
Offices of chiropractors	8041
Offices of optometrists	8042
Offices of health practitioners, nec	8049
Legal services	8100
Individual and family services	8321
Job training and related services	8331
Social services, nec	8399
Business associations	8611
Professional organizations	8621
Labor organizations	8631
Civic and social associations	8641
Political organizations	8651
Membership organizations	8699
Miscellaneous services	8900
Executive offices	9111
Legislative bodies	9121
Executive and legislative off. comb.	9131
General govt., nec	9199
Courts	9211
Legal counsel and prosecution	9222
Public order and safety, nec	9229
Public finance, taxation, and M.P.	9311
Adm. of educational programs	9411
Adm. of public health programs	9431
Adm. of soc., manpower, and inc. mat. p.	9441
Adm. of vet. aff. exp. health ins.	9451
Air and water res. and solid waste mgt.	9511
Land, mineral wildlife and forest cons.	9512
Adm. of housing programs	9531
Adm. of urban plan. and comm. and rural dev.	9532
Adm. of general economic programs	9611
Regulation and adm. of transp. prog.	9621
Reg. and adm. of comm., elec., gas, and other util.	9631
Reg. of agr. marketing and commodities	9641
Reg. licensing and insp. of misc. com. sec.	9651

HOTEL/MOTEL

Short Title	SIC Code
Hotels, motels, and tourist courts	7011
Rooming and boarding houses	7021
Membership basis organization hotels	7041

SCHOOLS

Short Title	SIC Code
Primary and secondary schools	8211

UNIVERSITIES

Short Title	SIC Code
Colleges and universities, nec	8221
Junior Colleges and tech institutes	8222
Correspondence schools	8241
Business and secretarial schools	8244
Vocational schools	8249
Schools and educational services, nec	8299

HEALTH

Short Title	SIC Code
Skilled nursing care facilities	8051
Nursing and personal care, nec	8059
General medical and surgical hosp.	8062
Psychiatric hospitals	8063
Specialty hospitals, exc. psych.	8069
Medical laboratories	8071
Dental laboratories	8072
Outpatient care facilities	8081
Health and allied services, nec	8091
Residential care	8361

OTHER

Short Title	SIC Code
Retail bakeries - baking and selling	5462
Gasoline service stations	5541
Laundry cleaning and garment service	7210
Power laundries, family and comm.	7211
Garment pressing and cleaner	7212
Linen supply	7213
Diaper service	7214
Coin-operated laundries and cleaning	7215
Dry cleaning plants, except rug	7216
Carpet and upholstery cleaning	7217
Industrial launderers	7218
Laundry and garment service, nec	7219
Funeral service and crematories	7261

OTHER (cont'd)

Short Title	SIC Code
Miscellaneous personal services	7299
Top and body repair shops	7531
Tire retreading and repair shops	7534
Paint shops	7535
General automotive repair shops	7538
Automotive repair shops, nec	7539
Motion pic. theaters, exc. drive-in	7832
Dance halls, studios, and schools	7911
Billiard and pool establishments	7932
Bowling alleys	7933
Membership sports and rec. clubs	7997
Libraries and information centers	8231
Museums, botanical, zoolog. gardens	8400
Religious organization	8661
Correctional institutions	9223

Difficult to Classify

(these codes may be needed in some cases)

Short Title	SIC Code
Railroad transportation	4000
Local and suburban transportation	4100
Trucking local and long distance	4210
Local trucking, without storage	4212
Trucking, except local	4213
Water transportation	4400
Transportation by air	4500
Pipe lines, except natural gas	4600
Inspection and weighing services	4782
Packing and crating	4783
Transportation services, nec	4789
Communications	4800
Electric, gas, and sanitary services	4900
Freezer and locker meat provisioners	5422
Fruit stores and vegetable markets	5431
Miscellaneous food stores	5499
Dwelling operators, except apts.	6514
Mobile home site operators	6515
Sporting and recreational camps	7032
Trailering parks, for transients	7033
Research and development laboratories	7391
Photofinishing laboratories	7395
Commercial testing laboratories	7397
Passenger car rental and leasing	7512
Truck rental and leasing	7513

Difficult to Classify

(these codes may be needed in some cases)

Short Title	SIC Code
Utility trailer rental	7519
Parking lots	7523
Parking structures	7525
Car washes	7542
Automotive services, nec	7549
Motion picture production, except TV	7813
Motion picture production for TV	7814
Services allied to motion pictures	7819
Motion picture film exchanges	7823
Film or tape distribution for TV	7824
Motion picture distribution services	7829
Drive-in motion picture theaters	7833
Theatrical producers and services	7922
Entertainers and entertainment groups	7929
Sports clubs and promoters	7941
Racing, including track operations	7948
Public golf course	7992
Coin-operated amusement devices	7993
Amusement parks	7996
Amusement and recreation, nec	7999
Child day care services	8351
Private households	8811
Correctional institutions	9223
National security	9711

Appendix C

EXAMPLE

EBER Nonresidential Energy Performance Monitoring

PROJECT DESCRIPTION FORM

1. Project or Program Name(s): COMMERCIAL MONITORING – INITIAL FIELD TESTING

   Sponsor: DOE – OFFICE OF BUILDINGS AND COMMUNITY SYSTEMS

   Project or Program ID: EBERC∅1

   Project or Program Contact(s):

T. R. SHARP	OAK RIDGE NATIONAL LABORATORY
Name	Address
615 / 574-3559	P.O. BOX 2008
Telephone: area code / number	
	OAK RIDGE TN 37831
	City State Zip code

2. Number of Buildings in Project or Program Covered Using These Forms:

   Number: 1

   Description: SMALL, STAND-ALONE BANK BUILDING

3. Project Goals, Objectives, and/or Research Questions Addressed:

   1) Evaluate savings from operational changes in a small commercial building.
   2) Obtain a detailed hourly end-use data set to support research.
   3) Develop performance monitoring approach for measuring building energy use.

4. General description of the energy improvements made to the building, building systems, or operations, etc., during the project that account for the cost and energy savings:

   Programmable thermostat installed in place of existing mechanical thermostat in primary (largest) zone. Setback/setup implemented in primary zone. Two secondary HVAC systems were interfaced with the auxiliary relay of the programmable thermostat. The auxiliary relays function as a time-clock switch and thus supply timed on/off control of the two secondary systems relative to the occupied and unoccupied periods.

EBER Nonresidential Energy Performance Monitoring

ANALYSIS METHODS AND RESULTS SUMMARY FORM

1. Experimental Design (circle the appropriate classification)

On/Off   Before/After   Test-Reference   Sim. Occupancy   Non-Exp. Reference   Eng. Field Test

Other (explain): ______

Explain any control/treatment groups ______

2. Approach (circle the appropriate entries)

Level of Detail: Whole Building Data   End Use Data   System/Equipment Data

Basis for Calculated Savings: Regression(s)   Dynamic Modeling   Calibrated Simulation   Other

Name of Special Simulation, Regression, or "Other" Modeling Tool: ______

Explain "Other" Modeling Basis: ______

If Regression-Based Approach, explain: Define acronyms or terms below	Regression Model(s)	Units
(EXAMPLE:	heating energy/day vs HDD/day	Btu/day vs °F-days/day
Tavg. = avg. daily outdoor temp.	heating energy/day vs. Tavg	Btu/day vs. °F
	cooling energy/day vs. Tavg	kWh/day vs. °F

3. Savings Results

Energy Savings:

Annual EUI (kBtu/ft²) TOTAL EUI Before	TOTAL EUI After	HEATING Before	HEATING After	COOLING Before	COOLING After	Annual BPI (Btu/ft²-DD) HEATING Before	HEATING After	COOLING Before	COOLING After	Other Index of Interest (Define units)
140	124	54	42	20	16	14.2	11.2	14.1	11.1	

Values normalized for temperature differences.

Electric Demand Savings:

Summer (kW) Before	Summer (kW) After	Winter (kW) Before	Winter (kW) After	Other (kW) (explain below) Before	Other (kW) After
29	31				

Cost Savings: Annual Energy cost Savings ($)	Annual Demand Cost Savings ($)	Annual O&M Cost savings ($)
$800	0	NA

Describe results in simple terms, explain how energy, demand, and O&M cost savings were estimated, and describe important effects of weather and other normalizations: Total EUI values above also normalized for baseload difference. Demand increase was due to an increase in baseload. Building did not incur demand charges.

4. Level of Confidence in Results

Describe confidence in savings estimates for each savings value above. Give 95% confidence limits if possible.
Linear models of end-use data provided excellent predictors of building energy use. Generally, model correlation coefficients exceeded 0.90.

5. Costs and Cost Effectiveness

Cost of the retrofit or efficiency improvement ($)	Life of improvement (yrs)	Additional O&M cost, if any ($/yr)
$600	10	Not evaluated.

Describe factors affecting cost and other costs that should be known: ½ cost = materials, ½ cost = labor

Simple payback (years): 1   Other cost effectiveness measure: ______ (Define units)

6. Improvements in Amenities

Describe any important changes in amenities resulting from the efficiency improvement, such as notable changes in thermal confort, lighting quality, noise, etc. Occupants noted improved comfort in zone where electronic thermostat was installed.

EBER Nonresidential Energy Performance Monitoring

PERFORMANCE DATA REQUIREMENTS FORM

— — Refer to Table 1 and the Data Transfer Form for specific requirements — —

1. Billing Data

Copies of utility and fuel supplier statements must be supplied for the building. These data must describe the (approximately) monthly consumptions for each fuel, the electric demand when available, and the dates of the billing periods. If these statements do not provide monthly results (such as when a bulk fuel like oil is used), monthly fuel use must be measured and reported.

Periods covered by the billing data:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Before Improvement	After Improvement
(12 months minimum)	(12 months minimum)*
01 / 87 to 02 / 88 (mo year mo year)	03 / 88 to 03 / 89 (mo year mo year)

*Projects with submetering may provide three months minimum data after the improvement with optional update to 12 months at a later time.

2. Submetered or Detailed Data

Provide submetered or detailed data as available. The maximum breakdown accepted will be by major end use, e.g., lighting, cooling, heating, water heating, and other. Data for individual measurement channels cannot be accepted unless they are for a systems analysis project or they describe an entire end use. A major end use is considered to account for at least 10% of the total annual energy consumption.

Recording Interval: hourly daily weekly 15-min. other

circle applicable categories explain:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Periods covered by the submetered or detailed data:

Before Improvement	After Improvement
01 / 18 / 87 to 02 / 29 / 88 (mo day year mo day year)	03 / 01 / 88 to 09 / 30 / 88 (mo day year mo day year)

3. Temperature and Weather Data

Temperature data must be provided for periods covering before and after the improvement to match the billing or submetering periods. Additional weather data may be provided as appropriate to the project and as available.

Temperature Data Type: daily max. and min. integrated averages

Recording Interval: hourly daily weekly 15-min. other

circle applicable categories explain:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Periods covered by the temperature (and other) data:

Before Improvement	After Improvement
01 / 18 / 87 to 02 / 29 / 88 (mo day year mo day year)	03 / 01 / 88 to 09 / 30 / 88 (mo day year mo day year)

Describe other weather data that are provided: NONE

EBER Nonresidential Energy Performance Monitoring
BUILDING DESCRIPTION DATA FORM — *page 1*

Building ID: BANK This page covers: Before condition ✓ After ✓ Date: 5-30-89
Building location: KNOXVILLE (city) TN (state) 37922 (zip code)
Project/program ID: EBERC01 Prepared by: T. R. SHARP

1. General Data and Building Envelope

Age category: (circle one) 1900 or before 1901-1920 1921-1945 1946-1960 1961-1970 1971-1973 1974-1980 1981-present

BECA building type code: SOFF Total floor area: 4750 (ft^2) Year of latest renovation: NA

BECA Building Type Codes

ASEM - Assembly Buildings	AUTO - Auto Sales and Service	GROC - Grocery Stores	RETL - Retail Stores	SHCN - Shopping Centers
REST - Restaurants	SECN - Second. Schools & Colleges	HOTL - Hotels/Motels	WARE - Warehouses	OTHR - Other
ELEM - Elementary Schools	NURS - Nursing Homes	HOSP - Hospitals	CLIN - Clinics	CORR - Correction Centers
SOFF - Small Office Building (< 10,000 ft^2)	LOFF - Large Office Building (≥ 10,000 ft^2)	INDS - Conditioned Industrial		

Floor area of latest additions: NA (ft^2) ____ (ft^2) ____ (ft^2) Number of stories: 2
Year completed: ____ ____ ____

Floor area and volume:	Heated (ft^2/ft^3)	Cooled (ft^2/ft^3)	Unconditioned (ft^2/ft^3)	Stories above ground:
Above grade:	3175 / 25,400	3175 / 25,400	0 / 0	1
Below grade:	850 / 6,800	850 / 6,800	720 / 5,760	
Atrium:	NA /	/	/	

Roof pitch: 4/12 (in./in.) Exposed roof area: 3636 (ft^2) Roof insulated at: ceiling level ✓ roof level ___
Average roof estimated U-value (Btu/h-ft^2-F) 0.04 Ground-coupled floor area: 3175 (ft^2)
Average estimated opaque wall U-value (Btu/h-ft^2-F) 0.08 Common walls: 0 (%)
Describe variances in roof, walls, and floor below.

Building shell construction codes
- Above grade walls: 1 Doors: 1
- Below grade walls: 2 Roof: 2
- Atrium walls: 6 Floor: 1

(If code '0' is used, describe below.)

Walls: 0-other, 1-wood frame, 2-masonry, 3-concrete, 4-metal, 5-glass, 6-none
Doors: 0-other, 1-standard doors (including mixed wood, metal, or glass), 2-large roll-up, 3-air doors
Roof: 0-other, 1-concrete deck, 2-wood deck, 3-metal deck, 4-mixed
Floor: 0-other, 1-slab on grade, 2-slab below grade, 3-suspended with insulation, 4-suspended without insulation

For exterior doors type 2 or type 3 next to conditioned space, total area is: Ø (ft^2)

Wall/glazing information
Primary glazing type: 100 (% of total glazing) Est. U-value 1 (Btu/h-ft^2-F)
(circle those that apply) Single Double Triple Clear Tinted Reflective Other Fixed Operable
Secondary glazing: ____ (% of tototal glazing) Est. U-value ____ (Btu/h-ft^2-F)
(circle those that apply) Single Double Triple Clear Tinted Reflective Other Fixed Operable

Orientation	N East	South E	S West	North W
Above grade gross wall area (ft^2)	533	805	533	805
Glazing area (ft^2)	126	80	27	100
Shading by overhangs (y or n)	N	N	N	Y
Shading by fins (y or n)	N	N	N	N
Photos attached showing facade (y or n)	N	N	N	N

Floor plan sketch(es) attached (y or n) Y

Maintenance: In-house ___ (%) | Contr., cont. 100 (%) | Contr., as needed ___ (%) | Owner/tenant ___ (%) | Other ___ (%)

Description of variances: ____________________

EBER Nonresidential Energy Performance Monitoring
BUILDING DESCRIPTION DATA FORM — *page 2*

Building ID: BANK This page covers: Before condition ✓ After ✓ Date: 5-30-89

2. Tenant Information

Tenancy breakdown (% of floor area): ____ % leased/rented ____ % owner-occupied ____ % other

Tenant No.	Tenant Name	Area (ft²)	SIC code (see App. B)	Utilities paid by tenant (y or n)
0	COMMON	Ø		
1	BANK STAFF	4750	6000	Y

Total floor area (ft²): 4750

Description of variances: ____________

3. Building Zone Information (minimum zone size is 10% of tenant area)

Tenant/ Zone No.	Use Code	Zonal Area (ft²)	Zonal Ceiling height (ft)	Occupied Setpoint (F)		Unoccupied Setpoint (F)	
				heating	cooling	heating	cooling
1A	105	2450	8	72	76	57	86
1B	300	700	8	72	76	57	86
1C	900	720	8	72	76	57	86
1D	606	720	8	NA	NA	NA	NA

Description of variances: SETPOINTS ABOVE REFLECT AFTER CONDITION.
BEFORE: Unoccup. setpts = occup. setpts = 72 (htg) & 76 (cooling).

4. Zone Schedule and Occupancy

(use times from 00:00–23:59)

Tenant/Zone No.	Day of week:	Mon	Tues	Wed	Thu	Fri	Sat	Sun	Hol
1A	Hour open	08:30	08:30	08:30	08:30	08:30			
	Hour closed	16:00	1600	1600	1600	1800			
	Occupant-hrs	130	130	130	130	140			
1B	Hour open	SAME							
	Hour closed								
	Occupant-hrs	13	13	13	13	14			
1C	Hour open	SAME							
	Hour closed								
	Occupant-hrs	6	6	6	6	7			
1D	Hour open	SAME							
	Hour closed								
	Occupant-hrs	0	0	0	0	0			
	Hour open								
	Hour closed								
	Occupant-hrs								
	Hour open								
	Hour closed								
	Occupant-hrs								

EBER Nonresidential Energy Performance Monitoring

BUILDING DESCRIPTION DATA FORM — *page 3*

Building ID: BANK   This page covers: Before condition ✓ After ✓ Date: 5-30-89

4. Zone Schedule and Occupancy (cont'd)

(use times from 00:00–23:59)

Tenant/Zone No.	Day of week:	Mon	Tues	Wed	Thu	Fri	Sat	Sun	Hol
Tenant/Zone No.: ______	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ______	Hour open								
	Hour closed								
	Occupant-hrs								

Description of variances and zones with variable occupancy: ______

5. Systems Data

HVAC Systems (See page 5 of the forms for descriptions of the HVAC type codes.)

System ID No.	HVAC Type Code	Controls Code	Tenant/Zones Served	Cooling (kBtu/h)	Heating (kBtu/h)	Pkg/Scndy (see codes)	Fuel Code
S1	PSZ	b-4	1A	100	126	p+s	e
S2	PSZ	b-2	1B	18	24	p+s	e
S3	PSZ	b-2	1B & 1C	29	38	p+s	e
S4							
S5							
S6							

Primary HVAC Systems Serving Secondary Units

System Code	Fuel Code	Input (kBtu/h)	Output (kBtu/h)	Pumps (kW)	Secondary Systems Served, ID Nos. Above
BW	g	216	188	0.2	S1, S2, S3

Description of variances: Control codes above reflect after condition. "BEFORE" used standard mechanical thermostat controls (Code 3). Codes 2 & 4 reflect new operation, see Project Desc. Form, Pt. 4.

Lighting

Tenant/ Zone Nos.	Lighting Code	Watts /Unit	No. of Units Total/Not working	Controls Code	Percent On Occ./Unocc.
1A	IF	80	21/0	M	100/15
1A	II	75	15/0	M	100/0
1A	II	150	15/0	M	100/66
1B	IF	80	8/0	M	100/0
1B	II	75	4/0	M	100/0
1C	IF	80	2/0	M	100/0
1D	II	75	2/0	M	50/0
O	EI	150	15/5	T	0/100

HVAC Type Codes (see p 5)

Single supply duct types: SZRH, PSZ, HP, HPWS, SZCI, RHFS, VAVS, PIU, PVAVS, CBVAV, VVT
Air mixing types: MZS, PMZS, DDS
Terminal unit types: TPFC, FPFC, TPIU, FPIU, PTAC, WHP
Heating only types: EBB, IR, FPH, HVSYS, UHT, UVT, WS

Controls Codes

h-heating, c-cooling, b-both
1-none (on/off manual), 2-timeclock, 3-thermostat
4-smart thermostat, 5-EMCS

Pkg/Scndy Codes

p-packaged unit (unitary eqpt.)
s-secondary unit served by primary system (below)
p+s-packaged + secondary

Fuel Codes

e-electricity, g-natural gas, ol-distillate fuel oil (#1 or 2), oh-other fuel oil, c-coal, w-wood, ch-chilled water from outside the building, s-steam from outside the building

Primary System Codes

BW-hot water boiler, BS-steam boiler, F-furnace, CC-centrifugal chiller, CA-abosrption chiller, CAR-air-cooled reciprocating chiller, CWR- water-cooled reciprocating chiller, CAS- air-cooled screw chiller, CWS- water-cooled screw chiller, CT-cooling tower, EC-evaporative condenser, EV-evaporative cooler

Lighting Codes

Type	Interior	Exterior
Standard fluorescent	IF	EF
High-eff. fluorescent	IFH	EFH
Incandescent	II	EI
Neon	IN	EN
HID	IHID	EHID
Other	IO	EO

Control Codes

M-manual, T-timer, P-photocell/daylight dimming, O-other

EBER Nonresidential Energy Performance Monitoring
BUILDING DESCRIPTION DATA FORM — *page 4*

Building ID: BANK This page covers: Before condition ✓ After ✓ Date: 5-30-89

5. Systems (cont'd)

Lighting (cont'd))

Tenant/ Zone Nos.	Lighting Code	Watts /Unit	No. of Units Total/Not working	Controls Code	Percent On Occ./Unocc.

Lighting Codes

Type	Interior	Exterior
Standard fluorescent	IF	EF
High-eff. fluorescent	IFH	EFH
Incandescent	II	EI
Neon	IN	EN
HID	IHID	EHID
Other	IO	EO

Control Codes

M-manual, T-timer, P-photocell/daylight dimming, O-other

Description of variances: Replacement of non-working exterior incandescent lamps known to be a major contributor to increasing baseload energy use & demand. All units were working in the "AFTER" condition. ("BEFORE" condition is shown in table)

Other Major Energy Consuming Systems

System ID	Tenant/ Zone Nos.	Type Code	Fuel Code	Connected kW

Type Codes for Other Energy Systems

FOD-food preparation, REF-chillers, refrigerators, freezers, and other equipment for cold generation, DPT-significant computer or electric/electronic equipment (including video games), SAN-sanitation equipment such as in a laundry or kitchen, LAB-laboratory equipment, SHP-shop or manufacturing equipment, SPE-specialty equipment not covered by other categories, VNT-ventilation equipment not part of the HVAC supply system, such as return or exhaust fans and exhaust hoods, VTR-vertical transport such as elevators and escalators

Description of variances:

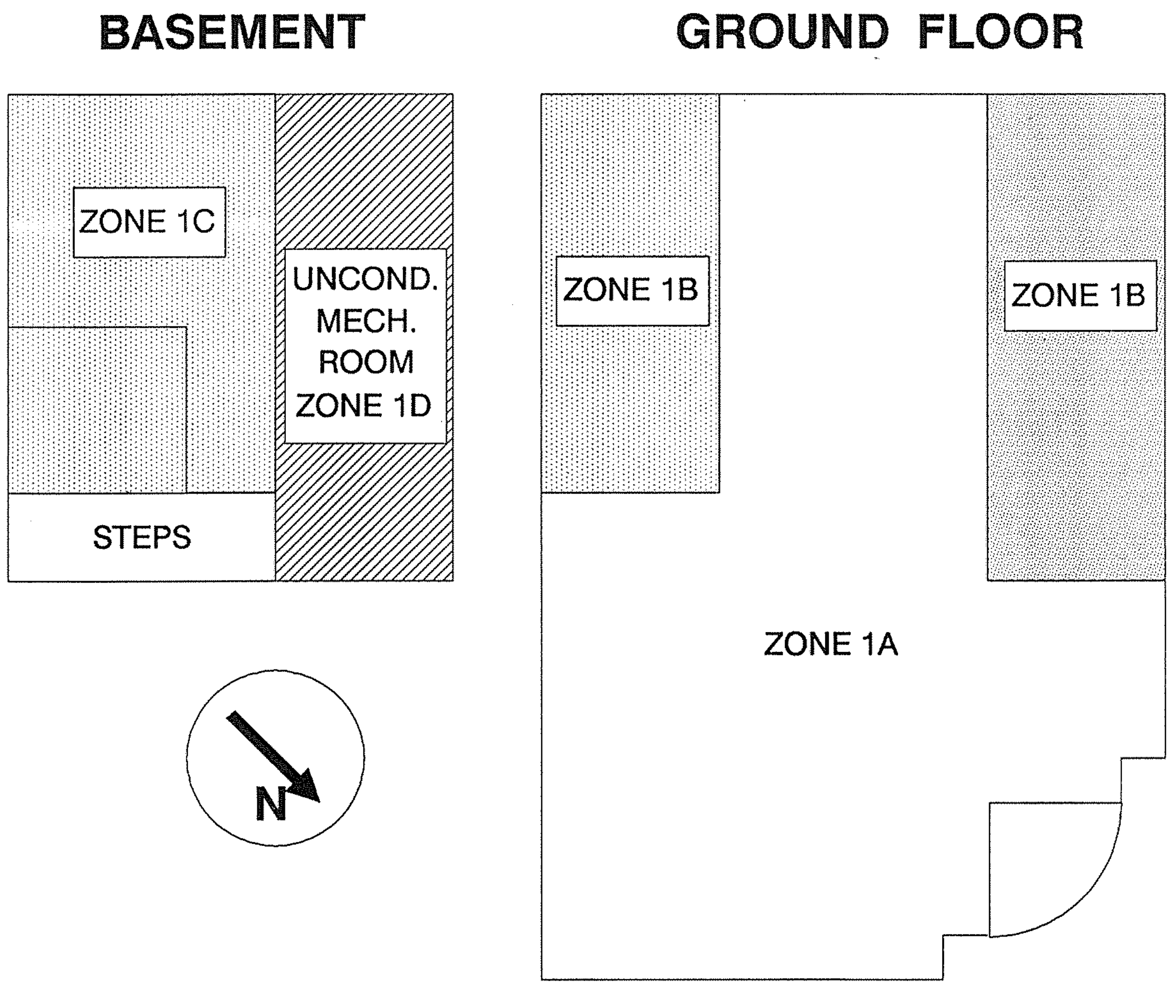
6. Monthly Energy and Fuel

Energy Utility or Supplier	Fuel Code	System ID Nos. of Supplied HVAC or Other Systems	Number of Meters
Lenoir City Utilities Bd.	e	All	1
Knoxville Utilities Bd.	g	All	1

7. Energy Improvements Being Evaluated

Energy Imp. Code	Description	Tenant/Zone Nos. or System ID Nos. Affected	Installation Day or Period	Cost ($000's)	Savings ($000's)/yr
MKC	SMART THERMOSTAT	All	3/01/88 to 3/01/88	0.6	0.8
			/ to /		
			/ to /		
			/ to /		

Description of variances: All zones impacted, see Project Desc. Form, Part 4.



Functional Use Zones for Bank

Appendix D

PROTOCOL DATA FORMS

EBER Nonresidential Energy Performance Monitoring
PROJECT DESCRIPTION FORM

1. Project or Program Name(s): ____________________

   ____

   Sponsor: ____________________

   Project or Program ID: ____________________

   Project or Program Contact(s):

   ____________________ Name

   ____________________ Address

   ______/______________ Telephone: area code / number

   ____

   ____________________ City State Zip code

2. Number of Buildings in Project or Program Covered Using These Forms:

   Number: ____________

   Description: ____________________

   ____

3. Project Goals, Objectives, and/or Research Questions Addressed:

   ____

   ____

   ____

   ____

   ____

4. General description of the energy improvements made to the building, building systems, or operations, etc., during the project that account for the cost and energy savings:

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

EBER Nonresidential Energy Performance Monitoring

ANALYSIS METHODS AND RESULTS SUMMARY FORM

1. Experimental Design (circle the appropriate classification)

On/Off Before/After Test-Reference Sim. Occupancy Non-Exp. Reference Eng. Field Test

Other (explain): ____________________

Explain any control/treatment groups ____________________

2. Approach (circle the appropriate entries)

Level of Detail: Whole Building Data End Use Data System/Equipment Data

Basis for Calculated Savings: Regression(s) Dynamic Modeling Calibrated Simulation Other

Name of Special Simulation, Regression, or "Other" Modeling Tool: ____________________

Explain "Other" Modeling Basis: ____________________

If Regression-Based Approach, explain: Regression Model(s) Units

Define acronyms or terms below (EXAMPLE: heating energy/day vs HDD/day Btu/day vs °F-days/day

3. Savings Results

Energy Savings: Annual EUI (kBtu/ft^2) Annual BPI (Btu/ft^2-DD) Other Index of Interest (Define units)

TOTAL EUI Before	TOTAL EUI After	HEATING Before	HEATING After	COOLING Before	COOLING After	HEATING Before	HEATING After	COOLING Before	COOLING After

Electric Demand Savings: Summer (kW) Before After Winter (kW) Before After Other (kW) (explain below) Before After

Cost Savings: Annual Energy cost Savings ($) Annual Demand Cost Savings ($) Annual O&M Cost savings ($)

Describe results in simple terms, explain how energy, demand, and O&M cost savings were estimated, and describe important effects of weather and other normalizations: ____________________

4. Level of Confidence in Results

Describe confidence in savings estimates for each savings value above. Give 95% confidence limits if possible.

5. Costs and Cost Effectiveness

Cost of the retrofit or efficiency improvement ($) Life of improvement (yrs) Additional O&M cost, if any ($/yr)

Describe factors affecting cost and other costs that should be known: ____________________

Simple payback (years): __________ Other cost effectiveness measure: ____________________ (Define units)

6. Improvements in Amenities

Describe any important changes in amenities resulting from the efficiency improvement, such as notable changes in thermal confort, lighting quality, noise, etc. ____________________

EBER Nonresidential Energy Performance Monitoring
PERFORMANCE DATA REQUIREMENTS FORM

— — Refer to Table 1 and the Data Transfer Form for specific requirements — —

1. Billing Data

Copies of utility and fuel supplier statements must be supplied for the building. These data must describe the (approximately) monthly consumptions for each fuel, the electric demand when available, and the dates of the billing periods. If these statements do not provide monthly results (such as when a bulk fuel like oil is used), monthly fuel use must be measured and reported.

Periods covered by the billing data:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Before Improvement	After Improvement
(12 months minimum)	(12 months minimum)*
___/___ to ___/___	___/___ to ___/___
mo year mo year	mo year mo year

*Projects with submetering may provide three months minimum data after the improvement with optional update to 12 months at a later time.

2. Submetered or Detailed Data

Provide submetered or detailed data as available. The maximum breakdown accepted will be by major end use, e.g., lighting, cooling, heating, water heating, and other. Data for individual measurement channels cannot be accepted unless they are for a systems analysis project or they describe an entire end use. A major end use is considered to account for at least 10% of the total annual energy consumption.

Recording Interval: hourly daily weekly 15-min. other
circle applicable categories explain:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Periods covered by the submetered or detailed data:

Before Improvement	After Improvement
___/___/___ to ___/___/___	___/___/___ to ___/___/___
mo day year mo day year	mo day year mo day year

3. Temperature and Weather Data

Temperature data must be provided for periods covering before and after the improvement to match the billing or submetering periods. Additional weather data may be provided as appropriate to the project and as available.

Temperature Data Type: daily max. and min. integrated averages

Recording Interval: hourly daily weekly 15-min. other
circle applicable categories explain:

Note: Data may be provided on computer recording media. Refer to the Data Transfer Form for requirements.

Periods covered by the temperature (and other) data:

Before Improvement	After Improvement
___/___/___ to ___/___/___	___/___/___ to ___/___/___
mo day year mo day year	mo day year mo day year

Describe other weather data that are provided: ______________________

EBER Nonresidential Energy Performance Monitoring

BUILDING DESCRIPTION DATA FORM — *page 1*

Building ID: ____________ This page covers: Before condition ___ After ___ Date: ____________

Building location: ____
city state zip code

Project/program ID: ____________ Prepared by: ____________

1. General Data and Building Envelope

Age category: (circle one) 1900 or before 1901-1920 1921-1945 1946-1960 1961-1970 1971-1973 1974-1980 1981-present

BECA building type code: ______ Total floor area: ________ (ft^2) Year of latest renovation: ______

BECA Building Type Codes

ASEM - Assembly Buildings	AUTO - Auto Sales and Service	GROC - Grocery Stores	RETL - Retail Stores	SHCN - Shopping Centers
REST - Restaurants	SECN - Second. Schools & Colleges	HOTL - Hotels/Motels	WARE - Warehouses	OTHR - Other
ELEM - Elementary Schools	NURS - Nursing Homes	HOSP - Hospitals	CLIN - Clinics	CORR - Correction Centers
SOFF - Small Office Building (< 10,000 ft^2)	LOFF - Large Office Building (≥ 10,000 ft^2)	INDS - Conditioned Industrial		

Floor area of latest additions: ________ (ft^2) ________ (ft^2) ________ (ft^2) Number of stories:

Year completed: ______ ______ ______ ______

Floor area and volume:	Heated (ft^2/ft^3)	Cooled (ft^2/ft^3)	Unconditioned (ft^2/ft^3)	Stories above ground:
Above grade:	____/____	____/____	____/____	____
Below grade:	____/____	____/____	____/____	
Atrium:	____/____	____/____	____/____	____

Roof pitch: _____ (in./in.) Exposed roof area: ________ (ft^2) Roof insulated at: ceiling level ___ roof level ___

Average roof estimated U-value (Btu/h-ft^2-F) ________ Ground-coupled floor area: ________ (ft^2)

Average estimated opaque wall U-value (Btu/h-ft^2-F) ________ Common walls: _____ (%)

Describe variances in roof, walls, and floor below.

Building shell construction codes

Above grade walls: _____ Doors: _____

Below grade walls: _____ Roof: _____

Atrium walls: _____ Floor: _____

(If code '0' is used, describe below.)

Walls: 0-other, 1-wood frame, 2-masonry, 3-concrete, 4-metal, 5-glass, 6-none
Doors: 0-other, 1-standard doors (including mixed wood, metal, or glass), 2-large roll-up, 3-air doors
Roof: 0-other, 1-concrete deck, 2-wood deck, 3-metal deck, 4-mixed
Floor: 0-other, 1-slab on grade, 2-slab below grade, 3-suspended with insulation, 4-suspended without insulation

For exterior doors type 2 or type 3 next to conditioned space, total area is: _____ (ft^2)

Wall/glazing information

Primary glazing type: ____ (% of total glazing) Est. U-value _____ (Btu/h-ft^2-F)

(circle those that apply) Single Double Triple Clear Tinted Reflective Other Fixed Operable

Secondary glazing: ____ (% of tototal glazing) Est. U-value _____ (Btu/h-ft^2-F)

(circle those that apply) Single Double Triple Clear Tinted Reflective Other Fixed Operable

	Orientation			
	East	South	West	North
Above grade gross wall area (ft^2)				
Glazing area (ft^2)				
Shading by overhangs (y or n)				
Shading by fins (y or n)				
Photos attached showing facade (y or n)				

Floor plan sketch(es) attached (y or n) _____

Maintenance:	In-house ___ (%)	Contr., cont. ___ (%)	Contr., as needed ___ (%)	Owner/tenant ___ (%)	Other ___ (%)

Description of variances: ____

EBER Nonresidential Energy Performance Monitoring

BUILDING DESCRIPTION DATA FORM — *page 2*

Building ID: ____________________ This page covers: Before condition ___ After ___ Date: ________________

2. Tenant Information

Tenancy breakdown (% of floor area): ____ % leased/rented ____ % owner-occupied ____ % other

Tenant No.	Tenant Name	Area (ft^2)	SIC code (see App. B)	Utilities paid by tenant (y or n)
0	COMMON			

Total floor area (ft^2): ______________

Description of variances: ____

____

3. Building Zone Information (minimum zone size is 10% of tenant area)

Tenant/ Zone No.	Use Code	Zonal Area (ft^2)	Zonal Ceiling height (ft)	Occupied Setpoint (F)		Unoccupied Setpoint (F)	
				heating	cooling	heating	cooling

Description of variances: ____

____

4. Zone Schedule and Occupancy (use times from 00:00–23:59)

	Day of week:	Mon	Tues	Wed	Thu	Fri	Sat	Sun	Hol
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								

EBER Nonresidential Energy Performance Monitoring
BUILDING DESCRIPTION DATA FORM — *page 3*

Building ID: ____________ This page covers: Before condition ___ After ___ Date: ____________

4. Zone Schedule and Occupancy (cont'd) (use times from 00:00–23:59)

	Day of week:	Mon	Tues	Wed	Thu	Fri	Sat	Sun	Hol
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								
Tenant/Zone No.: ________	Hour open								
	Hour closed								
	Occupant-hrs								

Description of variances and zones with variable occupancy: ____________

5. Systems Data

HVAC Systems (See page 5 of the forms for descriptions of the HVAC type codes.)

System ID No.	HVAC Type Code	Controls Code	Tenant/Zones Served	Cooling (kBtu/h)	Heating (kBtu/h)	Pkg/Scndy (see codes)	Fuel Code
__S1							
__S2							
__S3							
__S4							
__S5							
__S6							

Primary HVAC Systems Serving Secondary Units

System Code	Fuel Code	Input (kBtu/h)	Output (kBtu/h)	Pumps (kW)	Secondary Systems Served, ID Nos. Above

Description of variances: ____________

Lighting

Tenant/ Zone Nos.	Lighting Code	Watts /Unit	No. of Units Total/Not working	Controls Code	Percent On Occ./Unocc.

HVAC Type Codes (see p 5)

Single supply duct types: SZRH, PSZ, HP, HPWS, SZCI, RHFS, VAVS, PIU, PVAVS, CBVAV, VVT
Air mixing types: MZS, PMZS, DDS
Terminal unit types: TPFC, FPFC, TPIU, FPIU, PTAC, WHP
Heating only types: EBB, IR, FPH, HVSYS, UHT, UVT, WS

Controls Codes

h-heating, c-cooling, b-both
1-none (on/off manual), 2-timeclock, 3-thermostat 4-smart thermostat, 5-EMCS

Pkg/Scndy Codes

p-packaged unit (unitary eqpt.)
s-secondary unit served by primary system (below)
p+s-packaged + secondary

Fuel Codes

e-electricity, g-natural gas, ol-distillate fuel oil (#1 or 2), oh-other fuel oil, c-coal, w-wood, ch-chilled water from outside the building, s-steam from outside the building

Primary System Codes

BW-hot water boiler, BS-steam boiler, F-furnace, CC-centrifugal chiller, CA-abosrption chiller, CAR-air-cooled reciprocating chiller, CWR- water-cooled reciprocating chiller, CAS- air-cooled screw chiller, CWS- water-cooled screw chiller, CT-cooling tower, EC-evaporative condenser, EV-evaporative cooler

Lighting Codes

Type	Interior	Exterior
Standard fluorescent	IF	EF
High-eff. fluorescent	IFH	EFH
Incandescent	II	EI
Neon	IN	EN
HID	IHID	EHID
Other	IO	EO

Control Codes

M-manual, T-timer, P-photocell/daylight dimming, O-other

EBER Nonresidential Energy Performance Monitoring

BUILDING DESCRIPTION DATA FORM — *page 4*

Building ID: ____________ This page covers: Before condition ___ After ___ Date: ____________

5. Systems (cont'd)

Lighting (cont'd))

Tenant/ Zone Nos.	Lighting Code	Watts /Unit	No. of Units Total/Not working	Controls Code	Percent On Occ./Unocc.

Lighting Codes

Type	Interior	Exterior
Standard fluorescent	IF	EF
High-eff. fluorescent	IFH	EFH
Incandescent	II	EI
Neon	IN	EN
HID	IHID	EHID
Other	IO	EO

Control Codes

M-manual, T-timer, P-photocell/daylight dimming, O-other

Description of variances: ____________

Other Major Energy Consuming Systems

System ID	Tenant/ Zone Nos.	Type Code	Fuel Code	Connected kW

Type Codes for Other Energy Systems

FOD-food preparation, REF-chillers, refrigerators, freezers, and other equipment for cold generation, DPT-significant computer or electric/electronic equipment (including video games) , SAN-sanitation equipment such as in a laundry or kitchen, LAB-laboratory equipment, SHP-shop or manufacturing equipment, SPE-specialty equipment not covered by other categories, VNT-ventilation equipment not part of the HVAC supply system, such as return or exhaust fans and exhaust hoods, VTR-vertical transport such as elevators and escalators

Description of variances: ____________

6. Monthly Energy and Fuel

Energy Utility or Supplier	Fuel Code	System ID Nos. of Supplied HVAC or Other Systems	Number of Meters

7. Energy Improvements Being Evaluated

Energy Imp. Code	Description	Tenant/Zone Nos. or System ID Nos. Affected	Installation Day or Period	Cost ($000's)	Savings ($000's)/yr
			/__to__/		
			/__to__/		
			/__to__/		
			/__to__/		

Description of variances: ____________

EBER Nonresidential Energy Performance Monitoring

BUILDING DESCRIPTION DATA FORM — *page 5*
Additional Codes

Use Codes for Zone Functions

Conditioned Zones

101 – Sales	102 – Dining	103 – Classroom/Conference Room
104 – Medical/Dental	105 – Lobby	106 – Gymnasium
107 – Auditorium	108 – Shower Room	109 – Swimming Pool
110 – Restrooms	111 – Hallway	113 – Dentention
114 – Pharmacy	120 – Conditioned Parking	201 – Refrigerated Storage
202 – Conditioned Storage	300 – Office	400 – Food Preparation
501 – Computer	502 – Laboratory	503 – Duplication
504 – Shop	505 – Mech. or Elect. Room	510 – Manufacturing/Process
700 – Living Areas	800 – Vacant	900 – Other/Miscellaneous

Unconditioned Zones

203 – Unconditioned storage	603 - Unconditioned Parking	606 - Mech. or Elect. Room
600 - Other		

HVAC System Type Codes

Single supply duct types

SZRH — Single zone with reheat in some zones
PSZ — Packaged zingle zone with DX variable temperature cooling
HP — Air/air heat pump
HPWS — Water source heat pump
SZCI — Ceiling induction
RHFS — Reheat in all zones
VAVS — Variable air volume
PIU — Powered induction unit
PVAVS — Packaged VAV with DX cooling
CBVAV — VAV with ceiling bypass
VVT — Variable volume with terminal reheat

Air mixing types

MZS — Multizone system
PMZS — Packaged multizone with DX cooling
DDS — Dual duct

Terminal unit types

TPFC — Two pipe fan coil
FPFC — Four pipe fan coil
TPIU — Two pipe induction
FPIU — Four pipe induction
PTAC — Packaged terminal air conditioner
WHP — Water/air heat pump

Heating only types

EBB — Electric baseboard
IR — Infrared heaters
FPH — Panel heaters
HVSYS — Heating and ventilating system
UHT — Unit heater
UVT — Classroom unit ventilator
WS — Stack wall heaters

EBER Nonresidential Energy Performance Monitoring

DATA TRANSFER FORM

– – Data transferred using computer media must provide this information – –

1. Data Documentation

Title and/or acronym used to refer to the data: ______________________________

Data Contact Person(s):

______________________ ______________________

Name Address

_____/______________ ______________________

Telephone: area code / number

____

City State Zip code

Number of files being transferred: __________

Provide file IDs or names, description of file(s) (e.g., building IDs, time periods covered, fuels and submetered data covered), and size of file (no. of bytes, no. of records, record length):

____

____

____

____

____

Definition of data values:

(e.g., data headings or variable names, units of variables, location in the file, codes, missing value representation)

____

____

____

____

____

____

Appropriate reference citation for the data: ______________________________

Credit line for use in acknowledgments: ______________________________

2. Description of Data Transfer Media

Type of computer used to create the data file: ______________________

Operating system used to create the data file: ______________________

Software program used to create the data file: ______________________

Output file type (e.g., SAS, dBase, Lotus, DIF, etc.): ______________________

Diskette characteristics:

Disk ID: __________ Size: ___ 5–1/4" ___ 3–1/2" __________ Other

Total disk capacity (kBytes): ________

Tape characteristics:

Tape ID (VOL=SER=): __________ No. of tracks: _____ Density: _____

Label: ___ NL ___ SL __________ Other Record length (LRECL): ________

Record format (RECFM): ______ Block size (BLKSIZE): ________ Other: ______

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