Designation: E 1464 – 92 (Reapproved 1999)

An American National Standard

Standard Guide for Developing Energy Monitoring Protocols for Commercial and Institutional Buildings or Facilities[1]

This standard is issued under the fixed designation E 1464; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes a methodological approach to developing protocols for collecting empirical building or facility energy performance data.

1.2 The methodological approach covered in this guide is appropriate for commercial and institutional buildings or facilities, and with some adaptations, the approach can also be used for larger multifamily buildings or small industrial buildings or facilities.

1.3 This guide does not specify a complete project or experimental design, the hardware or software needed for data collection and data management, or the data analysis techniques to be used.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 631 Terminology of Building Constructions[2]

3. Terminology

3.1 *Definitions:* Terms related to buildings and facilities in this guide are defined in Terminology E 631.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *building*—generally used in this guide to refer to either a building or a facility.

4. Significance and Use

4.1 The collection of empirical data to determine building energy performance is an important but complex and costly activity. Careful development of energy monitoring projects can make a crucial difference in the value of project results relative to the expense.

4.2 Increasing the widespread understanding of how energy is used and the types of services it provides in commercial, institutional, and related (light industrial, large multifamily, and mixed commercial/residential) buildings has proved to be difficult. This difficulty arises from the following variables: the complexity of buildings as energy systems; the diversity of sizes, uses, schedules, and types of buildings; the changes in uses of buildings; and the mixture of uses within individual buildings. These factors make building energy performance and energy (and dollar) savings from energy improvements difficult to categorize and compare.

4.3 The audience for this guide is diverse, including energy suppliers such as utilities, building owners and managers, building occupants, designers, public and private research organizations, equipment manufacturers, and public regulators.

4.4 The user of this guide must be familiar with the fundamental techniques of engineering project management and energy performance data collection, data management, and data analysis. See Refs **(1-4)**[3] for a discussion of techniques related to the collection and analysis of energy performance data.

5. Procedure

5.1 Because initial goals and objectives often lead to excessive costs for field data collection, an iterative approach to project development is usually necessary. Once the goals and objectives are defined, costs for completing the project can be estimated. If the costs are too high, the goals and objectives are redefined (next iteration) to attempt to achieve more realistic costs, and further iterations are conducted as necessary.

5.2 *Project Development Activities*:

5.2.1 Identify project goals, objectives, questions to be answered by the project, and constraints such as the available budget. This activity should always be conducted early in project development.

5.2.2 Specify the minimum data products and the desired project output. The data needed to answer the project questions or meet specific objectives must be identified. The data

[1] This guide is under the jurisdiction of ASTM Committee E-6 on Performance of Buildings and is the direct responsibility of Subcommittee E6.25 on Overall Performance of Buildings.

Approved April 15, 1992. Published June 1992.

[2] *Annual Book of ASTM Standards*, Vol 04.11.

[3] The boldface numbers in parentheses refer to the list of references at the end of this guide.

manipulations or calculations necessary to provide the desired results should be identified. If possible, desired formats for the presentation of data results should be developed. The nature of the minimum expected final output should be defined.

5.2.3 Choose an experimental design that is appropriate for the project to be conducted **(1-3)**. The design is influenced by choices between the number of buildings to be monitored and the potential ability of the data collected to define the energy performance of interest. Increasing the number of buildings improves the potential usefulness of statistical measures of performance but also increases the cost. Increasing the measurement of physical quantities may improve the understanding of events in individual buildings, but it also increases the cost. Tradeoffs between costs and measurements may begin as the experimental design is being developed.

5.2.4 Develop data management procedures that can handle the (typically) large amounts of data collected. Computer resources are required to handle the data reasonably; some evaluation of required computer resources should therefore be conducted. The required computer resources depend on the volume of data to be collected, the methods used to determine the data quality, and the methods used to analyze the data. All data should be stored on computer media, and good quality assurance practices include storing archive copies of the data in more than one location in case of fire. Methods for determining data quality should be computer-based. Data quality should be examined as soon as possible after the data are collected to determine whether quality problems have arisen. Data archiving procedures should facilitate use of the chosen analysis methods or computer programs, which means that the formats required for analysis should be determined so that little data reprocessing is required. Data archiving procedures should also be well documented so that the data can be understood easily by analysts and good data transfer procedures (see Appendix X2) can be followed.

5.2.5 Specify minimum data analysis procedures (see Refs **(4-7)** for examples and guidance). The analysis procedures chosen will often affect the field data that must be collected. The specification should include the identification of analytical models, data reduction techniques, error analysis, and desired final output from the analysis to at least meet the requirements of 5.2.2. If the experimental design requires, sample sizes should be selected and the impacts of sample sizes on overall costs evaluated. Consideration should be given to the likelihood that advances in analytical methods will occur over the course of the project, which means that these minimum analysis procedures may require yearly review.

5.2.6 Specify the field data to be collected, based on an interactive consideration of required inputs for specific analysis methods and a definition of the building circumstances, conditions, or influences of interest. Data are of two major types: time-dependent and time-independent.

(*1*) Time-dependent data include weather and energy consumption data. Users must be careful that times are recorded consistently throughout the project for all parts of a project. Problems can arise when switching between daylight and standard time and when projects span more than one time zone. All times should be recorded in standard time.

(*2*) Time-independent data include specific items of interest necessary to define the project, such as descriptive data of the building or data on the costs of installing an energy-saving device. Projects should not proceed unless project developers establish a reasonably concrete procedure for describing the buildings in the project. See Refs **(1-3)** for guidance in these areas. Users must be careful to avoid the problem caused by defining a building by the Standard Industrial Classification (SIC) code **(8)** of the company that occupies the building. The function of the company may be manufacturing steel, while the function of the building is to be an office. Good practice for protocol guiding the collection of building energy performance data would dictate that the building be treated as an office, but use of the SIC code could mistakenly identify the building as an industrial building.

5.2.7 Resolve inconsistencies between desires (goals, objectives, project questions, and desired data) and realistic expectations for accomplishments, including resource and time constraints and uncertainties concerning the correct methods to use. At this point, project developers must be able to state the ramifications of resource limitations; to compare options available for conducting the project within the available resources or with incremental resources; and to determine final goals, objectives, project questions, and project output for the different options. If uncertainties in methods (especially data processing or analysis methods) are great at this point, larger-scale projects should usually be preceded by pilot-scale projects to permit exploratory investigation or the tuning of potential methods to meet project needs. Uncertainties in data results, such as plus or minus percents at the 90 or 95 % confidence level, should be quantified to the extent possible and stated as part of the expected project output.

5.2.8 Design a detailed project. Once realistic project goals, objectives, questions to be answered, and data output and formats are defined, the detailed project design begins in earnest. The usual project planning and management methods can be used here. Tasks are identified and assigned to appropriate organizations or personnel. Final hardware selection or adjustments are made. It may be necessary to recruit participants for the project. Data collection methods and schedules are developed. Data verification and quality assurance procedures, as well as data recording methods and formats, are developed. Maintenance requirements are identified and a maintenance plan designed. If possible, methods for dealing with changes over time in the building must be identified and tested. An analysis plan is designed; analyses must include both initial analysis or verification of data for reasonableness and accuracy and ongoing analysis of data that are received (for error-checking, at a minimum, and final analysis of the overall results). An example of some of the detailed project design considerations for one type of energy monitoring project (measurement of end use energy for a sample of approximately 50 buildings in the service territory of a specific electric utility) is given in Appendix X1.

5.2.9 Conduct the project. As stated in 1.2, details are not provided here. So many details exist concerning projects for collecting building energy performance data that volumes can and have been written on the subject. Developers and managers of projects should understand that analysis of project data is necessary to develop results, which is the purpose for conducting the project. A primary failing of many projects is that data collection is permitted to take on a life of its own at the expense of the analysis. Analysis should proceed during the project as a quality assurance measure and should continue after the data collection is complete. Because projects may take years to complete, the potential evolution in data analysis methods during this time may cause adjustments in final methods or reporting requirements (see 5.2.5). A commitment to some continuing analysis of project data can often enhance overall project results significantly.

6. Report

6.1 For basic reporting of the project results, include the following information:

6.1.1 *Project or Program Description*—General information, including identification of the project or program, the reason it was conducted, and improvements made to the buildings or systems studied;

6.1.2 *Data Management Procedures*—General description of the methods used to archive the data, to determine data quality, to prepare the data for analysis, and to perform the data analyses;

6.1.3 *Analysis Methods and Results*—Summary of analysis (evaluation) methods, experimental design, and project results;

6.1.4 *Performance Data*—Summaries of monthly (billing) data, submetred or detailed energy consumption data, demand data (if included), and temperature and weather data; and

6.1.5 *Building Description Data*—Survey data that describe each building and associated building systems, functional use areas, tenants, schedules, base energy data, and energy improvements, as appropriate.

6.2 For project or program description reporting, include the following information:

6.2.1 Project or program identification, sponsoring organization(s), and contact persons for those interested in learning more about the work;

6.2.2 The number of buildings involved in the project and a brief description of the types of buildings;

6.2.3 Project goals, objectives, and the questions addressed; and

6.2.4 A brief, general description of the energy improvements made to the building(s) or system(s) during the project (for example, shell retrofit, systems retrofit, and operation and maintenance changes).

6.3 For reporting of the data management procedures, include the following information:

6.3.1 The software used for checking data quality, archiving data, processing data before analysis, and performing data analyses;

6.3.2 The computer resources required to conduct the project and the amount of data archived (bytes); and

6.3.3 The number of files archived, a general description of the data contained in these files, and a description of the data available for transfer to others.

6.4 For reporting of the analysis methods and results, include a description of the following:

6.4.1 The experimental design and analysis approach used.

6.4.1.1 Typical experimental designs include on-off, before-after, test-reference, simulated occupancy, nonexperimental reference, and engineering field test (see 5.2.3).

6.4.1.2 The analysis approach is described by recording the degree to which the data should be detailed, the modeling methods 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.

6.4.2 *Basic Analysis Results of the Energy Monitoring*—Energy use indexes should always be reported. The annual energy use intensity, EUI (MJ/m^2 of floor area (kBtu/ft^2)), is an example of a simple index. The EUI based on the total amount of all fuels used in a building should be the minimum value reported. If possible, the EUIs for heating, cooling, lighting, or other end uses that are expected to be measured by the energy monitoring project or affected by energy improvements made during the project should also be reported. If improvements are made affecting heating or cooling, the annual building performance index, BPI, should be calculated and reported. BPI is expressed in MJ/m^2-DD (kBtu/ft^2-DD), where the following must be specified: nature of the energy quantity (MJ), the floor area used (m^2), and the nature of the DD (degree days). If possible, any other performance index that is helpful in interpreting the results should also be reported. Typical electric demand values (for example, peak kW) can also be provided, when appropriate, for interpreting project results and when available for the summer, winter, or other periods of importance. The effects of complicated demand price structures may cause difficulties in presenting useful demand values, so the most appropriate presentation should be selected, and the important features of the demand presentation should be described.

6.5 Summaries of energy performance data for the monitored buildings should be developed to provide an overview of the results of the project. Data summations or aggregations are often performed as part of the analysis conducted for the project, and it is often useful to report important intermediate results that help provide insight into the project results.

6.6 For projects impacted by outdoor temperatures, such as those in which heating or cooling energy are measured or are of interest, outdoor temperature data should be reported daily as the minimum time interval (these data are needed to support proper analysis). Daily temperature data derived from shorter-interval temperatures are acceptable, that is, hourly, 15-min, etc., that are averaged over the day. Daily outdoor temperature data can also be calculated from the average of daily maximum and minimum temperatures (two values).

6.7 Building description data provide an understanding of the complexities of the buildings in the project. Suggested building description data include the following: general and building envelope data, tenant information to define energy systems used by each tenant, building zone information to define the functional uses of the building and the types of energy systems serving these functional uses, information on zone schedule and occupancy, energy systems data, and descriptions of energy improvements being evaluated, if any.

7. Data Storage

7.1 An archive copy of the data collected for a project should be made, preferably on a computer medium such as magnetic disk or magnetic tape, so that the results can be shared with interested individuals. Suggestions to consider when transferring data to others are provided in Appendix X2. Users of this guide are cautioned that careful planning of the data archiving procedure is necessary (see 5.2.4) to ensure that the requirements of Appendix X2 may be met.

8. Keywords

8.1 building; building energy performance; commercial; data analysis; data management; data verification; energy monitoring; experiment; facility; institutional; project development; project planning; protocol

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE OF INTRODUCTORY MATERIAL FOR DETAILED PROJECT DESIGN HANDBOOK

X1.1 This appendix provides a specific example of the type of material necessary to define and manage an energy monitoring project. This example treats the case of an electric utility that wishes to measure the end-use electrical loads for a sample of customers. This example thus does not apply to all types of energy monitoring projects, but it does indicate the issues that most commercial or institutional energy monitoring projects should address in developing a monitoring protocol.

X1.2 *Project Objectives and Configuration:*

X1.2.1 The primary objective of the project is to collect two years worth of data on end-use load, internal temperatures, and associated customer characteristics for a sample of approximately 50 commercial buildings.

X1.2.2 The data collected will be applied for research purposes within the utility. The data from this project will be made available to the entire utility for uses such as load forecasting.

X1.2.3 A project office that serves as the direct operational base is established in the major operational city for the project. This office coordinates all aspects of data collection and interaction with the utility. All recruitments of buildings and data collection activities are based in this office, with the required staff and equipment available for immediate application to project activities.

X1.2.4 The utility approves each site for installation. A value engineer aids in this process by reviewing the proposed installation documents and associated costs. Utility representatives help facilitate contact with the customers in the buildings to be monitored.

X1.2.5 The example is as follows. An actual project handbook would typically be expanded to cover more topics.

1. Introduction

1.1 *Overview of Handbook*—This handbook documents procedures used in the commercial energy end-use monitoring project. Step-by-step instructions are provided on how to implement, maintain, and ultimately terminate end-use metering at a selected customer site. An explanation of the overall measurement concepts guiding the project is provided, and status tracking methods necessary to assess the progress of the project may be discussed. Procedures for collecting characteristics data are also enumerated.

1.2 *Handbook Organization*—In general, the handbook is organized in chronological order. Procedures for activities occurring early in the project (such as site selection) are described first, and activities occurring at the end of the project (such as the removal of monitoring equipment from a site) are described last. Certain chapters, however, contain general information that is applicable to all phases of the project. An appendix of reference materials is also provided. This appendix contains a glossary, a list of codes used in the project and their meanings, and other reference materials that may be useful in project activities.

2. Overview of Process

2.1 This section provides a brief overview of the activities conducted at each site that participates in the project. Each of these activities is described in detail in the body of this handbook.

2.2 *Selection and Recruitment*—Procedures for site selection are described. After the sites are selected, each of the potential sites is visited briefly during a walk-by survey. During this walk-by, limited preliminary data on each site are collected so that the sites can be classified accurately by categories of interest for the project. The recruitment process is then initiated. The object of recruitment is to encourage site owners to agree to participate in the project. To help facilitate the recruitment process, utility account representatives will be involved extensively in this stage.

2.3 *Initial Site Survey*—An initial site survey (ISS) is completed by a survey team at each site that has been recruited successfully. The primary objectives of the ISS are to determine whether the site is suitable for monitoring and to develop an estimate of the cost of monitoring the site. If the site consists of multiple buildings, a primary building (the building to be monitored at the end-use level) is identified in the ISS. Detailed information on the electrical (and gas) distribution system(s) in the building is then collected, along with some basic information on the site and building in general. After the ISS is completed, the survey team estimates the full cost of monitoring the site and recommends whether the site should be accepted for the study. The utility must approve the site for