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Load Research Manual

Volume 2: Fundamentals of Implementing Load Research Procedures

U. S. Department of Energy
Economic Regulatory Administration
Office of Utility Systems

Argonne National Laboratory
Energy and Environmental Systems Division

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LOAD RESEARCH MANUAL

Volume 2: Fundamentals of Implementing Load Research Procedures

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C. Grund, Jr.	Southern Company Services, Inc.
J. Leo	Middle South Services, Inc.

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FOREWORD

This manual will assist electric utilities and state regulatory authorities in investigating customer electricity demand as part of cost-of-service studies, rate design, marketing research, system design, load forecasting, rate reform analysis, and load management research. Load research also can be useful in determining the cost-effectiveness of time-of-day rates and load management. These types of studies and other conservation-related measures are being encouraged by the Department of Energy's Economic Regulatory Administration. The manual reviews the state of the art of load research and presents technical guidelines for implementing a load research study. Special attention is given to the concerns of small utilities that have no previous load research experience and to issues raised by the reporting requirements of Section 133 of the Public Utility Regulatory Policies Act (PURPA) of 1978, described in the Code of Federal Regulations (CFR), Title 18, Chapter 1, Subchapter K, Part 290,* Subpart D.

Volume 1 of this three-volume manual, entitled Load Research Procedures, includes an Executive Summary that presents an overview of load research procedures and PURPA requirements. Chapter 1 of this volume reviews the state of the art of load research techniques and describes a procedural framework within which load research can be conducted. An interpretation of PURPA requirements for reporting load data is presented in Chapter 2. Chapter 3 discusses load research problems faced by small utilities, which generally are relatively inexperienced in load research.

Volume 2, Fundamentals of Implementing Load Research Procedures, describes load research procedures in detail (Chapter 1). Chapter 2 of this volume compares ongoing load research programs at three utilities: Carolina Power and Light Company, Long Island Lighting Company, and Southern California Edison Company. Chapter 3 presents conclusions and suggestions regarding the implementation of load research programs. A load research bibliography and glossaries of load research and statistical terms are also included in Vol. 2.

Volume 3, Load Research for Advanced Technologies, deals with solar, wind, and cogeneration technologies. This volumes takes an engineering approach to load research for these emerging technologies.

Those inexperienced in load research should benefit from first obtaining an overview of the state of the art (Vol. 1, Chapter 1), then reviewing ongoing practices (Vol. 2, Chapter 2) and technical procedures (Vol. 2, Chapter 1), and finally reading the suggestions in Vol. 2, Chapter 3. Staff members of small utilities should also read Vol. 1, Chapter 3, which may help them set up a small load research program to comply with PURPA requirements. The more experienced practitioner may prefer to use this manual as a guidebook, using the extensive cross referencing of chapters provided. Utilities

*Part 290 is titled "Collection of Cost of Service Information under Section 133 of PURPA 1978." The regulations contained in Part 290 were issued by the Federal Energy Regulatory Commission as Order 48 (docket RM 79-6), originally issued September 28, 1979, and revised January 4, 1980.

that intend to incorporate new power generation technologies will find Vol. 3 useful. This manual attempts to discuss important issues, describe likely problems, and suggest useful guidelines. However, the procedures of the manual should not be unquestioningly adhered to, and load researchers should attempt to incorporate additional advice from utilities, other reports, and professional organizations.

This manual discusses present utility load research practices and problems. New load research techniques and equipment will of course evolve. Therefore, some discussions herein will inevitably become outdated and should be read with caution in future years.

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LOAD RESEARCH MANUAL

Volume 2: Fundamentals of Implementing Load Research Procedures

ABSTRACT

This three-volume manual presents technical guidelines for electric utility load research. Special attention is given to issues raised by the load data reporting requirements of the Public Utility Regulatory Policies Act of 1978 and to problems faced by smaller utilities that are initiating load research programs. In Volumes 1 and 2, procedures are suggested for determining data requirements for load research, establishing the size and customer composition of a load survey sample, selecting and using equipment to record customer electricity usage, processing data tapes from the recording equipment, and analyzing the data. Statistical techniques used in customer sampling are discussed in detail. The costs of load research also are estimated, and ongoing load research programs at three utilities are described. The manual includes guides to load research literature and glossaries of load research and statistical terms. In Volume 3, special load research procedures are presented for solar, wind, and cogeneration technologies.

1 TECHNICAL PROCEDURES FOR IMPLEMENTING LOAD RESEARCH

1.1 INTRODUCTION

This chapter describes detailed technical procedures for implementing load research, expanding on Vol. 1, Chapter 1. The discussion attempts to present a rigorous description of the foundations of load research for the novice load researcher and to serve as a reference manual for more-experienced practitioners; references to yet more-technical documents also are presented.

When implementing load research procedures, readers should temper theory with judgment and experience. The guidelines presented here should be viewed as suggestions rather than rigid rules. The utility's objectives and cost constraints must be considered when any load research technique is evaluated. Beginners should especially consider the advice of specialists and more-experienced practitioners from other utilities, consulting firms, or equipment manufacturers.

Load research proceeds in seven distinct stages:

- Data requirements and priorities must be defined. Since the purposes of a load survey affect later decisions, it is necessary to formulate them clearly. This entails defining the survey class (universe), primary sampling unit, recording interval, duration of the survey, reporting period, and "roll over" methods for transferring recording equipment to new sample customers.

- Load researchers, with the aid of statisticians, must design an efficient sample. Load parameters and sample characteristics should be estimated with a prespecified reliability and confidence. Sample customers should be scientifically selected. Researchers must decide if and how to stratify the sample; stratification procedures must be selected. The sample might be tested for its replication of population characteristics.

- After choosing a primary sample, a utility must exclude unwanted customers and secure the participation of other chosen customers. Questionnaires must be designed and the sample customers contacted. Bias can result from extensive exclusion and attrition, so care is essential here. Installation sites must be inspected. Procedures for selecting alternate sample customers must be devised.

- Recording equipment must be selected and installed on the premises of sample customers. Electricity usage patterns must be recorded on a permanent medium, such as magnetic tape. The research team faces decisions regarding equipment selection and installation and implementation of tests.

- The media upon which usage patterns are recorded must be translated to computer-compatible tape. Errors must be detected and corrected. Customer records with bad data must be discarded.

- Data must be stored on computer-compatible tapes or disks. Decisions must be made regarding format, interval, and tape structure.

- Procedures to display and analyze data must be devised. Loads can be analyzed in a variety of formats: by class, month, type of day, peak demand, or 24-hour load curve. Both tables and plots are useful for data display. Figure 1 illustrates a typical load research plan and indicates in which of the seven steps each of the activities occurs.

This chapter discusses each of the above stages, and three other aspects of load research, in the following order:

- Data requirements and priorities
- Sample design
- Customer participation and exclusion
- Recording equipment selection and installation
- Error detection and tape translation
- Data storage
- Data display and analysis
- Organization and management
- Estimated costs of load research
- Estimated timetable for load research

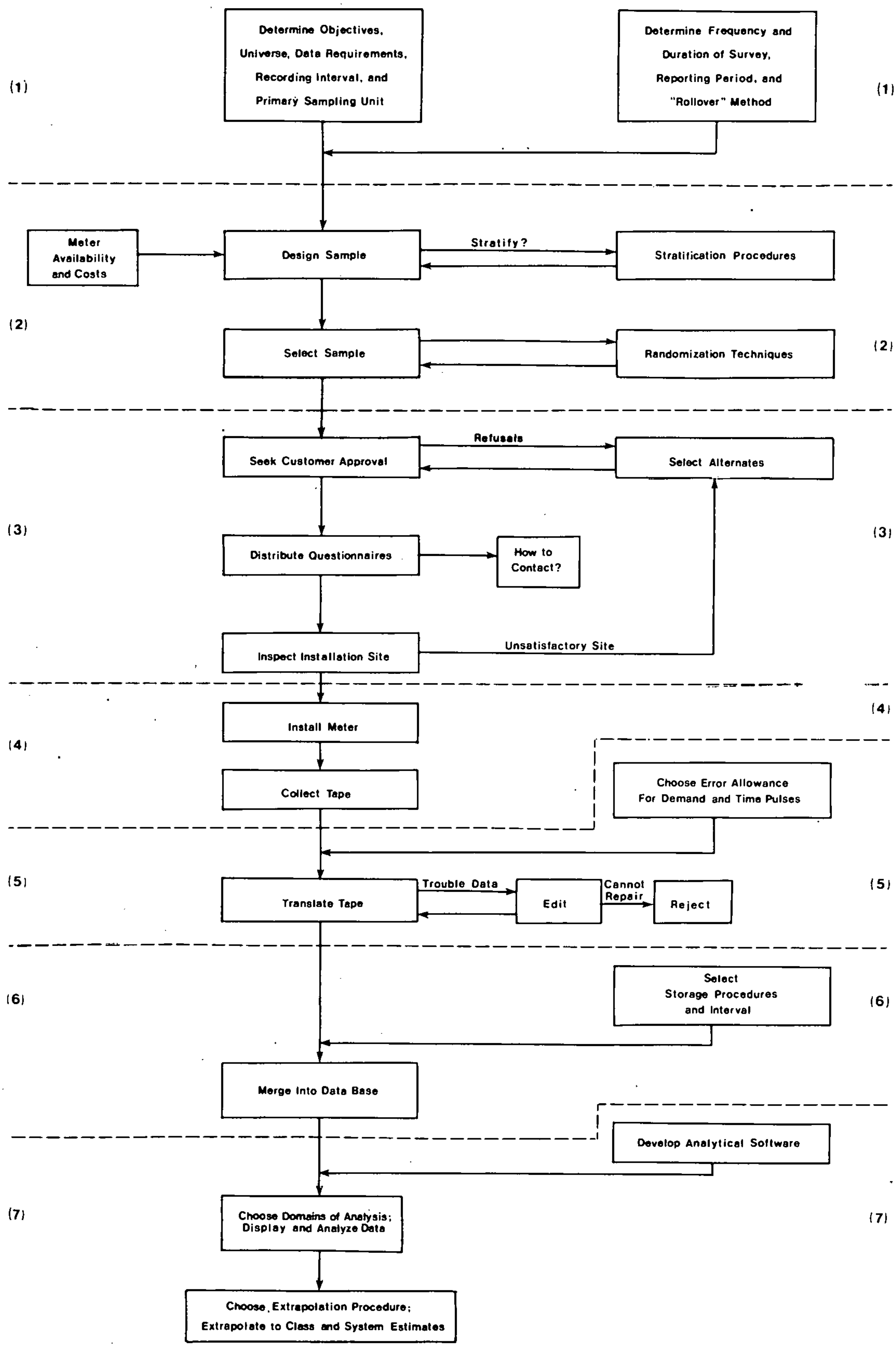

Fig. 1 Typical Load Research Plan

1.2 DATA REQUIREMENTS AND PRIORITIES

There are five traditional purposes for load research: cost-of-service allocation, rate design, marketing, load forecasting, and system design. In light of both the nation's heightened concern with energy conservation and the increasingly tight financial constraints that electric utilities face, new areas of concern -- rate reform and load management -- have emerged that pose new issues for load researchers. It is necessary to understand the research objectives to assess the data requirements for a load study.

Load research usually attempts to investigate a customer's or class's kilowatt demand at the hour of customer, class, and/or system peak; it often considers demand by hour. While attempting to assess the determinants of system peak demand, load researchers also can investigate individual group peak demands (coincident and noncoincident with system peak) and intragroup coincidence as well as varying load characteristics that result from different sizes of customer demand. To a lesser extent, research projects consider individual end uses by process and appliance -- especially space heating, air conditioning, and water heating. Demand characteristics by customer demographic attributes also have been explored.

Upon specifying their objectives, researchers must choose which parameters to investigate -- kilowatts, kilowatt-hours, kilovolt-amperes, Q hours (reactive voltampere-hours), etc. These can be investigated over a 24-hour period and for specific hours, such as the times of system, class, or individual customer peaks. Kilowatts or kilovolt-amperes can be recorded in 15-, 30-, or 60-min intervals. Parameters can be investigated by general class (residential, commercial, industrial), rate class, or subclass (e.g., residential water heating customers, commercial space heating customers). The load research team must also decide on the duration of the overall project, how frequently load surveys are to be conducted, how frequently data are to be reported, and efficient ways of transferring metering equipment from customer to customer.

1.2.1 <u>Traditional Uses of Load Research (see Table 1)</u>

Load research can be used to assess the utility's cost of serving various customer classes (residential, commercial, industrial), customer sizes (large, medium, and small), and customer types (residential electric space heating customers, residential electric water heating customers, etc.). Two important factors in estimating service costs for any class or customer are the class or customer peak and the class or customer contribution to the system peak. It is then necessary to examine likely peak loads, seasons, times, and load factors. A basic reporting format used by the Load Research Committee of the Association of Edison Illuminating Companies (AEIC) is structured to provide for compatibility of data (see Appendix A in this volume).

The original purpose of load research was to assist rate designers. Historically, full-cost-allocation procedures have been used to assign to each customer class its "responsibility" for production costs.[1] Utility marketing departments have attempted to promote appliances whose use would improve system performance, through, for example, promotional pricing of electric

Table 1 Applications of Load Research

<u>Cost-of-service studies and rate design</u>
Measure contribution to system, class, and individual customer peak or peaks
Obtain annual, seasonal, and monthly measures by class and subclass
Estimate load factors
<u>Rate design</u>
Evaluate cost-of-service information by major appliance ownership
Assess weather-sensitive load
Evaluate cost-of-service information by customer usage, type of customer (urban, rural), and customer income and age (lifeline rates)
<u>Marketing</u>
Measure typical appliance load characteristics and their relationship to system, class, and customer load curves
Measure effect of conservation devices on system, class, and customer load attributes
Evaluate procedures to improve load characteristics, reduce kilowatt demand or kilowatt-hour usage, and shift usage from peak to off-peak hours
<u>Load forecasting and system design</u>
Estimate annual, seasonal, and monthly peaks by system, class, subclass, and customer
Estimate typical load curves (annual, seasonal, monthly) by system, class, subclass, and customer
Gauge weekend/weekday load differential
Assess impact of weather discomfort on load
Measure effects of price, income, and demographic factors on demand and usage
Evaluate usage patterns by end use
<u>Time-of-use pricing</u>
Estimate price elasticities
Estimate long-run and short-run effects
Measure seasonal variation of price elasticities and differences in price elasticities of the weather-sensitive load by class and subclass
Gauge effect on utility revenues and costs
Assess impact of rate reform on system, class, and customer load curves
Measure income elasticities
<u>Load management</u>
Assess the effect of load management on system, class, and customer load curves
Measure seasonal differences in the effect of load management on load curves by class and subclass

space and water heating systems for residential customers. Load researchers have ascertained the load shapes of individual appliances and determined whether system performance would be improved if more such appliances were used. Because of the energy shortages of the 1970s and financial constraints on utilities, load research for this purpose has been drastically reduced. Individual appliance research, however, may still be useful to studies of appliance efficiencies and energy conservation.

In support of load forecasting, load research can provide important data regarding class and system peaks by month, season, or year. Each class's peak estimate may be extrapolated to estimate future load magnitudes. Alternatively, customer or class kilowatt demands may be regressed (see Sec. 1.8.2 of this chapter) upon several exogenous variables, e.g., appliance stocks, household characteristics, demographic variables, and electricity prices. Once kilowatt demand is represented as a function of these exogenous variables, it may be predicted from forecasts of the exogenous variables. Another type of forecasting procedure builds demand forecasts from individual end uses, such as industrial processes and residential appliances. If individual appliances (for example) are metered, average hourly demand per unit can be estimated. When average demand per appliance is multiplied by the expected future saturation of the appliance, hourly demands by appliance category can be obtained. These demands can be summed to obtain class and system loads.[2]

Optimal system expansion strategies are currently designed by elaborate linear programs developed by utilities or consulting firms.[3] Inputs to these programs include not only peak demand estimates, but (ideally) the estimated demands for all 8,760 hours in a year for 10 to 15 years into the future. System design efforts need information on customer and class time-of-day demand, usually in the form of average daily load curves by month, season, or year. The shape and magnitude of these load curves vary with customer size, weather discomfort, and appliance mix. In addition, these load curves vary by day of week and month of year, so temporal variations might be incorporated as well. Special attention to price elasticity, appliance mix, and load management is necessary to measure the effects of rate reform, enhanced efficiency standards, and effective load control on the annual load curve and the optimal system design. Load research can also be used to study transmission and distribution equipment requirements.

1.2.2 New Uses for Load Research (see Table 1)

Many electric utilities are now considering and adopting time-of-use pricing[4] (by time of day and by season) and load management.[5] Time-of-use rate design will require load research to estimate the various elements of load, such as contribution to system and class peaks.[6] It is also useful to assess the likelihood of a customer's demand occurring in any hour where a system, class, or individual customer peak might result. Additionally, the effect of time-of-use rates on company revenues requires attention (rates vary from their marginal costs in inverse relationship to their elasticities to effect the most efficient "second best" price framework).

To comply with Sections 111d, 113b, and 114 of PURPA,[4] utilities may design future load research to consider the following issues:

- What is the response of kilowatt-hour sales and hourly or peak kilowatt demand to modified customer, energy, and demand charges?
- What is the effect of changes in the breakpoints of a rate schedule on electricity consumption and demand(s)?
- What kind of influence would changing block prices have on usage and demand(s)?
- What would be the result of moving from declining block pricing to flat rate pricing or to increasing block pricing?
- What are the price responses of summer weather-sensitive, winter weather-sensitive, and base (weather-insensitive) sales and demands?
- How will changes in income distribution or demographics (e.g., percent elderly) affect aggregate electricity consumption? This bears upon the lifeline rate problem.
- What is the effect of income changes on kilowatt-hour usage and hourly kilowatt demand?
- What would be the effect of time-of-day rates on hourly demands?

Load management techniques will rely heavily on direct company controls, such as cycling or radio control, to shave the system peak.[5] Accordingly, load management experiments have investigated household and business usage patterns, especially for water heaters and air conditioners.

There are two basic categories of load management: end-use equipment, and communication and load control. End-use equipment management involves specific controls on individual appliances that enable system demand to be reduced at strategic times. Communication and load control comprise two subcategories: utility-controlled and customer-controlled devices. The former can be activated at the point of use or by the utility; utility activation can entail one-way or two-way communications. There is much overlap among load management techniques. Load research can examine customer behavior and electricity usage patterns under various load management strategies.

1.2.3 Aspects of Customer Usage

Load researchers sometimes consider aspects of customer electricity usage other than kilowatts and kilowatt-hours, such as power factor, kilovolt-amperes, and Q-hours. These measurements are especially useful to rate designers and system planners.

In addition to metering electricity demand, load researchers may also record weather data. The effect of weather conditions on demand might particularly concern distribution system planners; capacity must be built to meet certain peaks. Sometimes load research permits an estimate of line and transformer losses; these magnitudes also vary with weather conditions.

Recording intervals for data must be selected. Data are usually recorded in 15-, 30-, or 60-min intervals and can be stored and analyzed similarly. However, 5-min intervals also have been used. In storage, data can be aggregated but not disaggregated from its recorded status; for example, data recorded in 15-min intervals can be stored in 30- or 60-min intervals but not vice versa. Therefore, smaller recording intervals provide the most flexible data but entail greater translation costs.

1.2.4 Frequency and Duration of Survey

The frequency and the duration of a load survey must be selected; both choices depend on the survey's objectives. Research primarily aimed at measuring various customers' contributions to the annual system peak demand perhaps requires metering customers for no more than about three months. Attempts to estimate hourly demands of air conditioners or space heaters might last for a few months. However, most load research seems to last from six months to two years, if only to capture demand patterns in both winter and summer. (However, the importance of spring and fall months must not be underestimated, since these months are often used for system maintenance. Therefore, a representation of the system load curve in these months could be quite useful.) More than a few surveys have extended beyond a year. This is particularly true when load research is used to estimate the effects of time-of-use pricing. One British rate experiment that lasted seven years has been criticized for being too short to adequately reflect the long-run effects of time-of-use pricing.

A particular class can be resurveyed after a certain amount of time. New surveys can be especially useful before major rate overhauls, load forecasts, or utility commission hearings. More generally, a rapidly changing customer base might warrant a new survey. Since substantial "downtimes" are needed to design a new sample and install new meters, utilities have designed ways to transform "old samples" into useful "new samples."

The most thorough but most expensive customer sampling procedure is to test each class once a year (or once during the sample period). A utility must then have at least enough meters for a year's (or sample period's) sample customers. Unless the researchers are willing to permit downtime to install equipment for a new sample or "tune up" the old one (see below), more meters are required for the second year's sample customers. By using a downtime of a few months to relocate meters, the company can use the same meters on both first- and second-year customers, eliminating additional meter purchases.

"Cycling" is another way of avoiding extra meter costs. Shortly before the first sample period ends, the utility can begin to move the meters on the sample customers. These meters can be installed on second-sample customers as soon as possible. By the time the first sample period ends, a substantial fraction of the meters will have been transferred from first-sample to second-sample customers. Therefore, metering can begin immediately on the second sample. The next few months are spent relocating the remaining meters and bringing the second sample to full size.

Yet another way to circumvent excess meter costs is to tune up the sample. In the tune-up procedure, the company generally retains the same sample customers year after year. At the end of each reporting period, the sample strata are tested to see if they are indeed representative of their respective population strata (see Sec. 1.3.7 of this chapter). The researchers eliminate sample customers from those strata that overrepresent their population counterparts. They add sample customers to those strata that appear to underrepresent their population counterparts. These additional customers are not randomly selected but are instead chosen because they fall into the underrepresented strata.

Each approach has particular strengths and weaknesses. The downtime approach allows uninterrupted sampling throughout the survey period but survey data are not collected for several weeks or months. Depending on the survey's objectives and the months for which data are not collected, this approach may be acceptable. Cycling allows continual sampling but produces incomplete samples at the beginning and end of a sample period; this concern may be unimportant if sample periods are long and if excess meters are installed. If cycling is used, researchers must not only ensure adequate stratification and representativeness of total samples, they must also see that meters are removed and installed in a statistically correct manner to avoid sample bias in the cycling months. Additionally, cycling in commercial and industrial surveys is complicated since meters may not be transferred indiscriminately because customer service characteristics differ; e.g., single-phase meters cannot be used for three-phase customers. However, a homogeneous residential sample presents fewer problems for cycling. The tune-up approach allows continual metering but introduces nonrandom samples. Since customers are not randomly selected, sample statistics, as usually expressed, are no longer valid and must be modified. Accordingly, this procedure appears much less desirable in contrast with the other two, since it violates one of the basic principles of sampling.

Utilities that adopt discontinuous sampling procedures can avoid considerable sampling expense. It is possible for small utilities to survey one class per year; after four years, up to four classes could be surveyed, depending on the duration of the meter transfer procedure. (Meters can be cycled from class to class or a downtime can be used for meter relocation.) This approach can be modified by surveying one or two strata per year; after four years, four to eight strata could be surveyed and therefore total class parameters could be estimated. Researchers who sample different strata from the same class in different years must be very precise in extrapolating sample results to a selected year (see Sec. 1.8.3 of this chapter). Alternatively, all classes may be surveyed in one year, which could be useful if several utilities agree to share meter costs and rotate the meters among themselves. If the conditions are right, joint research efforts can be arranged between similar utilities to reduce metering expenses. (Vol. 1, Sec. 3.2, discusses this possibility in greater detail.)

1.2.5 Transferability of Data

Instead of conducting their own load research, many companies will use "best estimate" data available from other companies' research efforts. Various companies have done this already with varying degrees of success. The two companies' survey classes should be similar. Statistical tests can verify that similarity.[7] If external factors such as weather affect demand, these factors must also be similar in the two utilities' service areas.

Even if complete transferability is not possible, it might still be possible to use some of another utility's research. Section 1.3.4 of this chapter discusses how one company's estimated stratum or class variances can be used to help stratify another utility's sample. In appliance surveys, two utilities might expect different appliance capacities in their two service areas, but the load profiles themselves might be transferable (i.e., a utility can use the same profile and extrapolate upward or downward to estimate load curves for larger or smaller appliances).

There are three alternatives for obtaining "best estimate" load survey data, especially useful for small utilities; they are listed below in order of increasing credibility:

- The careful application of generally available industry data
- Pooled data collection involving several utilities
- Borrowed data gathered by another utility from a similar population

Generally available industry data can be especially useful in meeting the "best estimate" reporting requirement of PURPA. Borrowed data can be most relevant when obtained from a population similar to that of the borrowing utility. Even if two populations are different, however, some results may be transferable. For example, a load profile (obtained from another service area) may be useful even when its load magnitudes are not. Careful study of the two service areas is necessary to determine the significant differences in the demographic factors and weather conditions. It might be possible to make adjustments to relate the data between the two areas.[7]

Two or more cost-constrained utilities, each with a suboptimal number of meters, may pool their equipment and conduct a joint survey. Customer populations from the different service areas in a joint venture should be similar. Should significant differences exist, joint ventures may still be undertaken but each utility must interpret the results differently and make appropriate adjustments specific to its service area.

A recent report on load research identifies seven benefits to joint sampling:[8]

- The total number of customers to be sampled under a pooled approach would be less than that of individual load testing programs.
- The investment and operating costs of conducting load research would be spread over several utilities.
- Only one set of computer programs would need to be developed for extracting, editing, storing, and reporting the test data.

- Other items with high fixed costs, such as translators and spares, might be shared with an improved utilization rate.
- Delivery of bulk orders of recorders and translators should be faster, and unit costs might be lower.
- The timetable to acquire the operational knowledge and skills associated with a load test program would be reduced since all participants would learn simultaneously. The solution to operational problems would be shared among all participants through task force staffing.
- All software for edits, output reports, and graphs would be utilized by each of the participants when they conduct individual testing at a later date to supplement and/or verify the commonly gathered test data. Individual utility test data would be in the same computerized format for comparative studies among the participating utilities.

A utility may wish to borrow data obtained from a similar population in another utility's service area. Three steps are involved here: the required data must be identified, available data at other utilities must be evaluated, and the best data source must be selected and appropriate adjustments made in the data.

Data requirements depend on the objectives of the survey. They can be annual or season- or month-specific; peak hour (individual customer, class, or system) or 24-hour time-of-day; peak day (individual customer, class, or system) or typical day; or class-, customer-, or appliance-specific. Upon identifying necessary data, a utility must locate a viable donor utility. The Reznek and Gilbert Associates studies listed in the bibliography of this manual (this volume) are two compendia of load research reports. Additionally, annual AEIC reports provide further information (see Vol. 1, Appendix A).

From an initial list of possible donor candidates, the borrower must then carefully select the best donor. The decision may be affected by the following factors; the eventual choice depends on the relative weights that the borrower assigns to each factor.

- What data need to be borrowed?
- Where are they available?
- What was the candidate-donor utility's experimental design for generating the data?
- Can the information be used to represent the customers or end-use devices in the borrowing utility's service territory?
- Are there any constraints to physical transfer of the data?
- How much time is required to transfer the data?
- How much time and manpower are required to put the data into a usable format?

Two factors affect the degree of data transferability. First, the more data transferred, the greater the cost. Second, the more data transferred, the greater the flexibility of the resulting data bank. Long after the data transfer has been completed, analysis can be done to make the study relevant to a variety of purposes. Accordingly, a careful cost-benefit analysis of the transfer procedure is worth considering.

Customer characteristics in different service areas can be compared to determine the similarity of the populations, and it may be possible to adjust load data gathered from one population for the characteristics displayed by another. Information can be gathered on electricity usage and sociodemographic characteristics, economic factors, and weather conditions. State and federal publications, especially census documents, and utility records can provide usage and demographic information. Weather information (e.g., temperature, humidity, cloud cover, wind speed, and rainfall) can be obtained from the National Oceanic and Atmospheric Administration in Asheville, North Carolina.

Data transfer can be complicated not only by differences between the population in the two service areas but also by differences in the computer systems. Computer systems differ substantially both in design and operation; large expenditures of time, effort and money can be required to rectify problems caused by these differences. Hardware problems that might arise with tape transfer include discrepancies between the number of tape tracks, recording densities, tape-drive characteristics, labeling practices, and recording standards. Should any of these problems arise, an outside computation facility can copy the tape onto a compatible device. Alternatively, a medium other than tape can be used to transfer the data. Software problems can complicate the situation further. These result when the data on the donor tape are not compatible with the borrowing system's computer software. Problems can include labeled character sets, word length, binary or encoded data, and record blocking. Appropriate programs must be designed to transform a donor's tape into a format compatible with the borrowing system. Tapes should be validated prior to processing since various data errors and gaps may result from the transfer. For further information on load data transferability, see Ref. 9.

1.3 SAMPLE DESIGN

1.3.1 Introduction

This section discusses the fundamental procedures for sampling from a given population. These procedures include measuring reliability and confidence, selecting sampling techniques and randomization methods, defining strata, sizing the sample, allocating meters, and testing the sample's replication of the relevant characteristics of the population.

In a costless and error-free world, information regarding electricity demand could be obtained by surveying the entire population and calculating accurate statistics. Equipment and manpower costs make this approach inappropriate for all but the smallest populations. Rather, a portion of the population -- a sample -- is surveyed. Data are compiled, statistics are calculated, and inferences are drawn based on observations of this sample. The reliability of and confidence to be entrusted to sample statistics are functions of sample size -- the larger the sample, other things being equal, the more reliable the inferences. However, there is a point of diminishing returns in sample sizing, beyond which the benefits of increased reliability are more than offset by increased survey costs. The techniques of sample sizing concern selecting the optimal size for a sample.

Another way to enhance the reliability and confidence of the sample is to stratify the sample. By dividing the population into separate categories, called strata, and strategically choosing the allocation of meters to strata, one can increase sample reliability and confidence using a fixed number of meters. However, there is also a point of diminishing returns in stratification, beyond which more strata will only serve to reduce survey accuracy. Upon defining strata, it is necessary to allocate a number of meters (optimal or not) over the strata. The methods of strata design and meter allocation entail choosing the optimal number of strata in a survey, defining their breakpoints, and allocating the meters to the strata in an appropriate manner.

For a sample to be valid, it must be a probability sample, which means all elements of the population have a known probability of being included. When these probabilities are equal for all sample customers, the sample is a random sample[10,11]* and is said to be randomly selected. All random samples are therefore probability samples, but the equal probability condition of a random sample is not necessary for a valid sample. When a sample is not stratified, its customers are often completely randomly selected (i.e., each sample customer has the same probability of being included). On the other hand, sometimes there are benefits to selecting stratified samples with a disproportionate emphasis on certain strata relative to their shares in the population. Stratified samples, while they are not necessarily completely random, will often require randomly selected customers within each stratum. Therefore, randomization techniques are essential procedures to most load research. Additionally, statistical procedures are available to test whether sample customers adequately replicate the relevant characteristics of the population.

Sample design, a complex subject, is discussed in the following eight subsections:

- Sampling techniques
- Reliability and confidence
- Sample sizing
- Stratification procedures
- Randomization techniques
- Sample representativeness
- Forward stratification
- Concluding remarks

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*This is sometimes called an "epsem" (equal probability of selection method) sample.

As a general rule, two very different specialists should be involved in the sample design process. A trained sampling statistician can bring powerful mathematical techniques to bear on the problem. These techniques can enhance the precision of the sample. However, the insights of an experienced load researcher who understands the nature of the customers and the limitations of the data are essential. Interaction between the two is necessary for good load research.

1.3.2 Sampling Techniques

There are various ways to structure a sample. One must consider the survey's objectives and the population's characteristics in selecting the best way to construct a sample. Electricity customers' demands can be sampled in two ways: group metering, which records the aggregate demands of several customers, and individual customer (or appliance) metering. There are several ways to construct individually metered samples.

The researchers must first define the universe and the primary sampling unit. The universe (or population) is defined as the class of customers about whom the researcher is attempting to obtain information through sampling. Examples of universes include customer rate classes, customers owning certain appliances, or customers using electricity at a certain voltage. The units that are observed are termed primary sampling units. Loads can be observed by residence, customer, appliance, building, factory, transformer, or town. Primary sampling units can often be further disaggregated by account size, number of customers or transformers, or types of appliances owned. The definition of primary sampling units is, of course, contingent upon the prior definition of the universe. (For a good nonmathematical discussion of sampling terms and issues, see Ref. 12).

Occasionally, the definition of primary sampling unit is not immediately clear. If apartments are master-metered, it must be decided whether individual apartments or the aggregate complex will serve as the primary sampling unit. Similarly, researchers must decide whether two-family homes account for one or two primary sampling units. Some large industrial and commercial customers take delivery along several transmission or distribution lines; it must be decided how many primary sampling units are represented in these cases.

Load researchers can group meter several customers (usually residential) at once by monitoring the customer group's collective demand at the transformer or the branch feeder. Of course, individual customer detail is not possible, nor can the sample be chosen quite as scientifically as can be done with individual metering. It is also necessary to correct for line and transformer losses. However, a given degree of sampling precision might be obtained with lower metering costs; equivalently, a metering effort might effect a more reliable analysis if group metering is used. However, group metering is not always the better procedure and has lost favor with many load research teams although it may regain popularity with smaller companies. Group metering has advantages over individual metering under the following conditions:

- The survey's objectives do not warrant individual customer or appliance detail.
- The population is fairly homogeneous, so stratification will produce negligible improvements in the overall sample variance, reliability level, and confidence level.
- The researcher is fairly sure that the group-metered sample is representative of the population.
- The group-metering sites serve only the class under study and will not change over the term of the study.

Group metering is discussed in greater detail in Vol. 1, Sec. 3.2.

Individual customer sampling is the more popular sampling procedure among load researchers today. There are four common sampling procedures[13] of this type often used in designing load research samples: simple random sampling, stratified random sampling, cluster sampling, and systematic sampling. This list in no way exhausts all possible individual customer sampling procedures; for a more comprehensive taxonomy, see Ref. 14.

Simple random sampling (or unrestricted random sampling) is the most straightforward method.[11,15] The researcher defines the universe to be surveyed, deduces its appropriate size, and randomly selects a primary sample and several alternate samples. There is no effort to disaggregate the population into strata. Simple random sampling is most useful when the population is homogeneous and there are no identifiable strata where demand characteristics differ substantially. A danger arises if a large fraction of customers are small users; random selection will allocate only a few recorders to the largest customers.[16] Consequently, a small amount of total load will be metered.

In stratified sampling, the population is first divided into several nonoverlapping subpopulations, which together compose the entire population and serve as the basis for selecting the sample customers. These nonoverlapping subpopulations are called strata. After defining all strata, the researcher selects a sample from each stratum. If each stratum's sample is randomly selected, the procedure is termed stratified random sampling.[17] Stratification most enhances statistical precision when customer loads differ substantially across strata.

Even if each stratum's sample is randomly selected, the entire sample might not be considered a random sample. The entire sample is randomly selected if and only if each customer has an equal chance of selection. In stratified random sampling, it is often desirable to incorporate certain sample strata disproportionately to their population frequencies.[18] Though customers might be randomly selected within each stratum, there might then be unequal probabilities of selection across different strata.

Stratification can be "subjective" or "statistical." A utilitarian stratification may disaggregate the population into subpopulations of particular interest to the researcher. For example, this framework may be adopted if data of known precision are wanted for certain subpopulations such as rate classes or geographic regions, if administrative considerations dictate such a breakdown, or if different subpopulations exhibit different sampling problems (for more discussion of justifications for this procedure, see Ref. 19).

Statistical stratification attempts to stratify a population to enhance the precision of the sample's parameter estimates.[20] It therefore stratifies to enhance survey reliability and/or reduce necessary sample size. Statistical stratification procedures entail mathematically elegant techniques that were derived by sampling statisticians for use with highly stylized and reliable data. Load research data present serious measurement problems that reduce the efficiency of these theoretically powerful methods. Therefore, a great deal of caution must be exercised before using elaborate statistical paradigms with load research data. Their use especially requires the insights of both a trained sampling statistician and an experienced load researcher.

The third common sampling method is cluster sampling.[21] This entails randomly choosing sample observations by population group, e.g., by neighborhood; however, customers are still metered individually. Cluster sampling can be useful if one wants to survey each group, if population lists are not available, or if survey costs can be reduced considerably by having customers near each other. However, cluster sampling presents many more problems in ensuring sample accuracy. One must weigh objectives, expected cost reduction, and possibilities for bias when using this technique. A statistician should help design cluster samples since design problems are complex.[22] As always, an experienced load researcher should be consulted to identify problems in the utility's data.

Systematic sampling is possible when the population is ordered randomly. Following the random selection of the first customer, every k^{th} customer afterward is chosen to be in the sample.[23] Alternate samples can be similarly selected. One might obtain k using the formula:

$$k = N/n(i + 1)$$

where:

N = size of population,

n = size of sample, and

i = number of alternates to be chosen for each primary customer.

It is also possible to use this procedure with a stratified sample.[24]

Two-phase or double sampling procedures[25] can be useful to researchers who suspect substantial demographic and economic variation among customers and therefore have a valid basis for stratification but no firm evidence. In these procedures, the population is first surveyed with a large sample to obtain information on customer attributes other than electricity demand. Information obtained here is used for a second, smaller load research sample that is stratified on the basis of results obtained in the first survey.[26]

1.3.3 Reliability and Confidence

Prior to choosing an actual sample, a researcher must select the appropriate sample size. The larger the sample, all else being equal, the more reliable the study. In general, one must first determine the desired degree of precision and the budget for the survey. There are no rigid rules for choosing the desired reliability level; this decision depends on the survey objectives.

A subset of the population is sampled to estimate relevant population parameters (such as the average hourly demand of the population customers); these parameters are estimated by sample statistics. The average (or mean) of a sample parameter is an unbiased point estimate of its respective population parameter's expected value. (This is discussed in more detail in Appendix B, Sec. B.1, of this volume.) This does not mean that the sample mean perfectly estimates the population expected value; rather it implies that the sample mean is as likely to overestimate the expected value as it is to underestimate it.

Since sampling does not guarantee perfect estimation of the population parameter, not only sample mean but also the bandwidth surrounding it should be estimated. The bandwidth surrounding the mean is a numerical estimate of the uncertainty of the equality between the sample mean and its population expected value. If $\bar{X}$ is the sample mean, then a 5% bandwidth about X includes all points Y where $0.95\bar{X} \leq Y \leq 1.05\bar{X}$. Similarly, a 10% bandwidth includes all points Y where $0.90\bar{X} \leq Y \leq 1.10\bar{X}$. There are certain probabilities or confidences that the population parameter's expected value lies within the 5%, 10%, 15%, etc., bandwidth; these confidences increase as the size of the bandwidth increases. The half-length of the bandwidth (in the above examples, 5% and 10%) is the reliability of the sample estimate. As the bandwidth decreases in size, the reliability is enhanced.

Normally, utility load research surveys strive for 90% or 95% confidence and 5% or 10% reliability. This means that there are 90 or 95 chances in 100 that the population parameter Y falls within 5% or 10% of the sample estimate. The Federal Energy Regulatory Commission requires 90% confidence with 10% reliability (see Chapter 2 and Appendix F in this volume) for compliance with PURPA.

The larger the sample, the more certain one can be that the sample mean represents its population parameter's expected value. For a fixed confidence level, the relevant bandwidth, i.e., reliability, decreases as the sample size increases. Alternatively, as sample size increases, one may have more confidence that the population parameter falls within a fixed bandwidth of the sample estimate. Appendix B, Sec. B.1 (this volume), provides a more mathematical discussion of this problem.

1.3.4 Sample Sizing

This section includes a statistical discussion that demonstrates the conceptual framework involved in optimal sample sizing. A simple random sample will be used as an example. This conceptual framework can be extended to the more complex problems of correctly sizing a stratified sample. Before reading this section, the reader should read Sec. 1.3.3 and Appendix B, Sec. B.1 (both in this volume), to gain a general overview of the problem.[27]

Samples must be sufficiently large to allow load researchers to obtain statistics that exhibit the desired confidence and reliability. Since each additional customer entails further time and money expenses, researchers seek to minimize the number of customers while satisfying the necessary confidence and reliability requirements.

The variance of the sample mean, $\overline{X}$, of customer loads, $s^2_{\overline{X}}$, is defined (without a finite population correction) in Appendix B, Sec. B.1, as:

$$s^2_{\overline{X}} = s^2/n$$

where:

s^2 = sample variance of individual customer load, and

n = sample size.

The coefficient of variation V is defined as:

$$V = s_{\overline{X}}/\overline{X}$$

where:

$\overline{X}$ = sample mean of kWh or kW at hour i, and

$s_{\overline{X}}$ = standard deviation of the sample mean.

Since s^2 and $\overline{X}$ are expected to remain constant as the sample size, n, rises, $s^2_{\overline{X}}$ and V can be reduced by increasing n. As the sample size increases, the distribution of $\overline{X}$ about its expectation approaches normality (see Appendix B, Sec. B.1). If $\overline{X}$ is normally distributed about μ (the expected value of the population parameter), μ will lie in the interval $\overline{X} - s_{\overline{X}}$, $\overline{X} + s_{\overline{X}}$ with 68% confidence; $\overline{X} - 2s_{\overline{X}}$, $\overline{X} + 2s_{\overline{X}}$ with 95% confidence; $\overline{X} - 3s_{\overline{X}}$, $\overline{X} + 3s_{\overline{X}}$ with over 99% confidence. For any other level of confidence, e.g., 90%, the corresponding bandwidth adjustment Z (the standard normal deviate) can be read from the normal distribution table (see Appendix B, Sec. B.2); for example Z(90) = 1.645, which means that one can be 90% confident that μ lies between $\overline{X} - 1.645s_{\overline{X}}$ and $\overline{X} + 1.645s_{\overline{X}}$. Then the half-length of the bandwidth is $Zs_{\overline{X}}$ and the reliability level r is defined as:

$$r = Zs_{\overline{X}}/\overline{X} = ZV$$

For a fixed level of confidence and its corresponding Z, it is possible to reduce r, i.e., to enhance reliability, by increasing n and thereby reducing $s_{\overline{X}}$ and V. Alternatively, for a fixed reliability, one can assure more confidence, i.e., increase Z, by increasing n. Finally, it is possible to calculate the minimal sample size, n, required to effect any given degree of confidence and reliability.

However, this entire analysis requires prior estimation of the sample mean $\overline{X}$ and the sample variance s^2 (or the sample standard deviation). Unfortunately, a statistician cannot measure the sample mean, the sample variance, or the sample standard deviation until the sample data have been gathered and analyzed. By then, it is usually too late to sample more customers should the sample size prove too small, nor can excess sample customers be "refunded." The above discussion, while describing the general principles of sample sizing, requires additional information to be useful to a load research effort.

To estimate optimal sample size prior to selecting the sample, one must roughly estimate the mean and the standard deviation (or the variance) of the customer loads. There are at least three basic ways to estimate $\overline{X}$ and s. First, actual sample data from similar surveys conducted in the past may be used. Second, a small prior survey may be designed at additional cost; this might provide reasonable estimates of customer means and standard deviations. Third, intuition and managerial judgment might provide reasonable approximations.

After estimating $\overline{X}$, s, and s^2, the necessary sample size, n, may be calculated for any degree of confidence and reliability. Suppose one seeks to estimate the expected value of a population parameter with 90% confidence and a ±5% bandwidth. From the normal distribution table, Z(90) = 1.645. The reliability, r, is 0.05. Then r = Z(90)V. Since:

$$V = s_{\overline{X}}/\overline{X} = s/(\overline{X}\sqrt{n})$$

n can be expressed as:

$$n = (s/\overline{X}V)^2 = (sZ/r\overline{X})^2 \tag{1}$$

If one estimates the customer standard deviation to be 500 and the likely customer mean to be 1000, then s = 500, Z = 1.645, r = 0.05, and $\overline{X}$ = 1000 and the optimal n is:

$$n = \left[(500)(1.645)/(0.05)(1000)\right]^2 = 271$$

If one seeks a 95% confidence interval with ±5% reliability, Z rises to 1.96. Then the optimal sample size, n, increases:

$$n = \left[(500)(1.96)/(0.05)(1000)\right]^2 = 384$$

To reduce reliability (which means a higher value of r) to ±10%, r = 0.10 and the optimal sample size for 90% confidence is:

$$n = \left[(500)(1.645)/(0.10)(1000)\right]^2 = 68$$

and for 95% confidence:

$$n = \left[(500)(1.96)/(0.10)(1000)\right]^2 = 96$$

While the above formulas can be used to estimate optimal sample size, some utilities, especially smaller ones, cannot afford a large number of meters in their load research surveys. Therefore, load researchers should assess reliability and confidence for those meters that they actually do have. If these reliability and confidence levels are judged inadequate, researchers can then decide to obtain more meters, forego the survey, or undertake a joint effort with other utilities.

Suppose in the above discussion that only 60 meters were available. What reliability might be obtained with 90% confidence ($Z = 1.645$) and 95% confidence ($Z = 1.96$)? Since:

$$r = ZV = Zs/(\overline{X}\sqrt{n})$$

At 90% confidence, the reliability is:

$$r = (1.645)(500)/(1000\sqrt{60}) = 106 \text{ or } 10.6\%$$

At 95% confidence:

$$r = (1.96)(500)/(1000\sqrt{60}) = 1.265 \text{ or } 12.7\%$$

As more confidence is sought, estimates become less reliable (i.e., r rises). There is then a tradeoff between confidence and reliability when the sample size is fixed.

Alternatively, suppose a utility seeks to estimate how much confidence is possible with reliability levels of 5% and 10%. Since:

$$Z = r\overline{X}\sqrt{n}/s$$

At 5% reliability:

$$Z = (0.05)(1000)\sqrt{60}/500 = 0.77 \text{ (corresponding to 55\% confidence)}$$

At 10% reliability:

$$Z = (0.10)(1000)\sqrt{60}/500 = 1.55 \text{ (corresponding to 87\% confidence)}$$

The above discussion assumed that the sample size was small in relation to the population size. When this is not true, the variance of the sample mean must be adjusted with the finite population correction:

$$s^2_{\overline{x}} = (1 - f)s^2/n$$

where:

s^2 = variance of individual customer load,

n = sample size,

f = finite population correction = n/N, and

N = population size.

Then the optimal sample size must be adjusted:

$$n = s^2/(\overline{X}^2V^2 + s^2/N) \qquad (2)$$

The second term in the denominator of Eq. 2 differentiates this equation from Eq. 1. It is obvious that the optimal sample size, n, increases as N increases. This is relevant to instances where variances can be calculated from prior research.

When less than 30 customers are to be included in the sample, the t-statistic rather than the Z-statistic should be used to measure confidence and calculate necessary meter requirements. Appendix B, Sec. B.3 (this volume), describes this procedure.

1.3.5 Stratification Procedures*

To stratify a sample, five questions must be addressed:

- What variables should serve as the basis for stratification?
- What fraction of the entire sample should fall into each stratum, i.e., how should meters be allocated?
- What should the strata breakpoints be if customers are to be stratified on the basis of a continuous variable?
- How many strata should be defined?
- What is the optimal sample size?

Stratification Variables

From a statistical viewpoint, a sample should ideally be stratified on the basis of the variable being measured (see Sec. 1.3.2). For example, if one is concerned with measuring peak kilowatt demands, then the sample should be stratified on this basis. Unfortunately, most load research attempts to measure customer kilowatt demands, which are rarely available prior to the survey to serve as a basis for stratification. Consequently, the research variable cannot be used for stratification.

Even if these data were available, their use is still problematical. Customer kilowatt demands constantly change over months and years, and while it is possible to stratify a sample on the basis of some previous or current measure of demand, this measure might not reflect a customer's real usage level (e.g., a residential customer was on vacation during the measurement period). Additionally, customer usage may change significantly in the future, which is when the survey will be done. Appendix B, Sec. B.4 (this volume), discusses some procedures for stratifying a sample on the basis of expected future demands.

Given the variability in demand over the year, a possible stratification procedure might be to stratify the population on the basis of load for each hour of the year, i.e., on the basis of 8760 hourly loads. Although it is possible to stratify a sample on the basis of more than one research variable, the sample design becomes considerably more complex.[28] An alternative to the above procedure would be to represent the 8760 hourly demands with a single measure of usage.

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*For a more complete discussion, see Ref. 20.

It is not evident what measure of usage patterns should serve as a representative variable; possibilities include customer contribution to system or class peak, individual customer peak, customer load at a particular hour of the day (such as the expected peak hour), average hourly customer load over 24 hours of the day, or average customer load over 96 recording intervals. When relevant, loads can be measured as annual averages, as averages for a particular season or month, as averages for the peak week, or only on the peak day. Some researchers feel that a customer's annual or monthly kilowatt-hour usage best represents composite usage.

It is then useful to specify the most representative stratifying variable. This is useful to design procedures to circumvent data unavailability for the selection of the stratifying variable. If one choice has to be made, perhaps customer contribution to system peak is appropriate, although this choice still presents substantial problems. The following discussion will proceed as though this were the primary choice and discuss the resultant problems. However, this choice is made primarily for illustrative purposes and should not be interpreted as a recommendation of this stratifying variable. Similar analyses can be made for other stratifying variables.

When research variables are not available for sample stratification, the sample should be stratified on the basis of an observable variable that is correlated with the most representative unobserved one. A correlation coefficient, r, between two variables X and Y can be calculated as:

$$r = \sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})/s_x s_y(n - 1)$$

where:

n = number of observations,

$\bar{X}$ = mean of X variable,

$\bar{Y}$ = mean of Y variable,

s_x = standard deviation of X, and

s_y = standard deviation of Y

The value of r ranges between -1 and 1; the higher its absolute value, the more perfect the correlation. Appendix B, Sec. B.5 (this volume), discusses correlation coefficients in greater detail.

For example, if customer contribution to peak kilowatt demand is not known, annual or monthly customer energy use, available from the company's billing record, might be the only second choice as a stratification variable in a statistical framework. Other possible second choices include family size, consumer income, number of appliances, or rated appliance stock capacity, provided these data are available for every member of the population. Generally, however, this information is difficult to obtain.

A population may be encountered where information on the preferred stratification variable is available only for some customers; e.g., demand meters are put on some but not all commercial and industrial customers. In this case, the population can be divided into two groups, one group stratified by the preferred variable and the other by a correlated proxy or another second-choice variable.

A sample can be stratified by:

- Billing kilowatt demand, available from customer billing records
- Monthly kilowatt-hour sales, available from customer billing records
- Annual kilowatt-hour usage, available from customer billing records
- Selecting the sample from customers in one billing cycle and stratifying by monthly kilowatt-hour usage
- An exogenous variable other than kilowatt demand or kilowatt-hour usage (this variable could be discrete or continuous)
- An estimated proxy for actual kilowatt demand, which can be obtained from a linear regression of customer kilowatt demand (measured in previous surveys) on several exogenous variables, possibly including monthly or annual kilowatt-hour usage

Two-phase sampling (see Sec. 1.3.2, in this chapter) can be especially useful in selecting stratifying variables; the first-stage sample can provide data on important variables and their numerical ranges. Customer billing records often prove a useful source of information, especially in attempts to stratify by kilowatt-hours or kilowatts.

It is possible to stratify a sample on the basis of more than one variable, e.g., the presence or lack of electric heat and annual kilowatt-hour sales. Any mixture of discrete and continuous variables is possible; i.e., two-variable frameworks can have two discrete variables, two continuous variables, or one of each type. Additionally, any mixture of utilitarian and statistical frameworks is possible, although a "double statistical" stratification would be extremely timely, costly, and mathematically complex.

Table 2 summarizes the six techniques discussed above and their respective strengths and weaknesses. Each procedure has substantial problems that complicate the stratification process and detract from the statistical precision of any result. Yet a careful researcher must consider all of these methods and select the procedure that introduces the least distortion.

<u>Stratify by Billing Demand</u>. Large commercial and industrial customers are frequently billed not only for energy usage but also for kilowatt demand. This demand is usually measured at the time of the individual customer peak but is occasionally measured at the time of system peak. These billing demands could serve as stratifying variables.

Table 2 Strengths and Weaknesses of Stratification Procedures

Procedures	Strengths	Weaknesses	Best Used
1. Stratify by billing demand from customer billing records.	Only measure of kilowatt demand immediately available. Data often available for commercial and industrial customers.	Billing demand may not correspond to actual demand in any month. Billing demands may usually not coincide with each other or with system peak. Billing demands are rarely monitored by customer contribution to system peak. Data not available for residential sector.	When billing demands coincide with each other and system peak.
2. Stratify by monthly kilowatt-hours from customer billing records.	Might be best single proxy for kilowatt demand when billing demand is not available. Data readily available from billing records.	Billing cycles may create distorted usage data that are not related to kilowatt demand at a given hour i. Danger of nonrepresentative monthly usage.	When customer daily usage patterns do not differ much from day to day.
3. Stratify by annual kilowatt-hours from customer billing records.	Good proxy for kilowatt demand at a given hour i. Data readily available from billing records. Lessens the distortion from billing cycles. More apt to incorporate long-run usage levels.	Different customers with widely divergent seasonal usages may still have similar total annual usages.	When different customers do not display widely divergent seasonal usages or the causes of any divergence can be isolated.
4. Draw sample from one billing cycle and stratify by monthly kilowatt-hours.	Avoids billing cycle problems yet enables use of monthly kilowatt-hours. Data readily available from billing records.	Customers in chosen billing cycle must be similar to population as a whole; this can be a risky assumption.	When customers in one billing cycle are indeed representative of the population as a whole.

Table 2 (Cont'd)

Procedures	Strengths	Weaknesses	Best Used
5. Stratify by an exogenous variable other than 1, 2, 3, or 4 above.	Circumvents the above problems with kilowatt-hours and kilowatts. Can be used in tandem with 1, 2, 3, or 4 above.	Correlation between kilowatt demand and exogenous variable may be much weaker than in 1, 2, or 3 above. Other exogenous variable data may be unavailable or costly to gather.	When the above procedures are especially flawed. When reliable exogenous data can be obtained. Best used in conjunction with 1, 2, or 3 above.
6. Stratify with an estimated proxy for actual kilowatt demand, obtained from a linear regression.	Incorporates several possible exogenous variables. Acknowledges that several factors contribute to customer kilowatt demand. Produces better correlation between actual demand and estimated proxy than could exist between actual demand and any one exogenous variable.	Must use explanatory variables from above, with their attendant problems. Linear regression techniques always entail some forecasting error. Must estimate equation using customer demands obtained from previous research, which may not exist. More costly investment in time, labor, and computer resources.	When several exogenous variables can be measured well. When no one variable can adequately serve as a proxy for kilowatt demand. When reliable previous research has been effected.

Four problems arise with this approach. First, a month's billing demand is often determined as the greater of that month's peak kilowatt demand and some other demand measure, e.g., the average or maximum of the past six months' kilowatt demand. Consequently, a particular customer's billing demand for a given month might not correspond to actual demand during that month. Second, two customers' monthly billing demands may be measured over different days in the billing cycle; identical customers then may have different monthly billing demands if they are billed on different cycles. Third, individual customers' billing demands, even if measured in the desired month with no billing cycle problems, will usually not coincide among themselves or with the system peak. Sample stratification may be distorted since customer billing demands are not observed at the same hour. Fourth, if each customer is indeed billed for contribution to system peak rather than individual maximum demand, precision might be enhanced; however, few utilities bill industrial customers by these coincident demands.

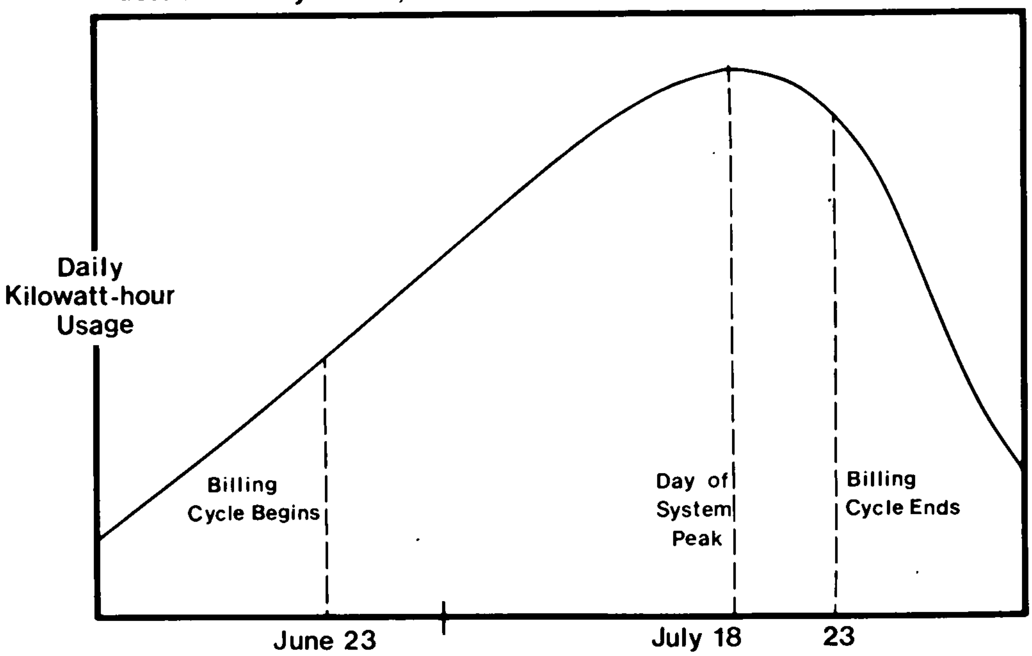
Stratify by Monthly Kilowatt-Hour Sales. Since residential customer kilowatt demand will rarely be available prior to the survey, monthly kilowatt-hours can be used as a proxy for kilowatt demand. (Commercial and industrial customers can also be stratified on the basis of monthly kilowatt-hour usage.) Unfortunately, the only monthly customer kilowatt-hour data available are from the company's billing records, which indicate what the customer was billed for in that month. Since residential customers are billed across 20 or so billing cycles, two otherwise identical customers can be billed for different electricity usages in any month if they do not fall into the same cycle (see Figure 2). This is especially likely in highly weather-sensitive seasons (when the annual peak usually occurs), where fluctuations in daily weather conditions produce wide variations in daily electricity usage. On the other hand, should daily usage patterns in a service area be basically fixed over the month, the use of billing kilowatt-hours might cause considerably less distortion. The degree of precision then depends on which month is chosen and the extent to which electricity usage changes from day to day.

Additionally, monthly kilowatt-hour sales can display fluctuations unrelated to the customer's long-run propensity to consume electricity. For example, a residential customer on vacation in a particular month might be billed for little usage in that month, yet may really be a sizable user when home. Furthermore, there will always be some estimated or prorated bills, adjustments in a month's billing date, and meter reading errors. Inevitably, certain customer readings will not take place as scheduled; the result may be a "long month" followed by a "short month." Finally, customers are often regrouped into different cycles to incorporate new residential subdivisions.

Stratify by Annual Kilowatt-Hour Sales. To circumvent the billing cycle problem, the sample might be stratified on the basis of electricity sales over a longer interval, such as one year, where billing cycle discrepancies, though they exist, produce less distortion.

Additionally, annual kilowatt-hour sales may provide a more accurate assessment of any customer's long-run propensity to consume electricity. The

Customer 1 July bill = 1,000 kWh



Customer 2 July bill = 800 kWh

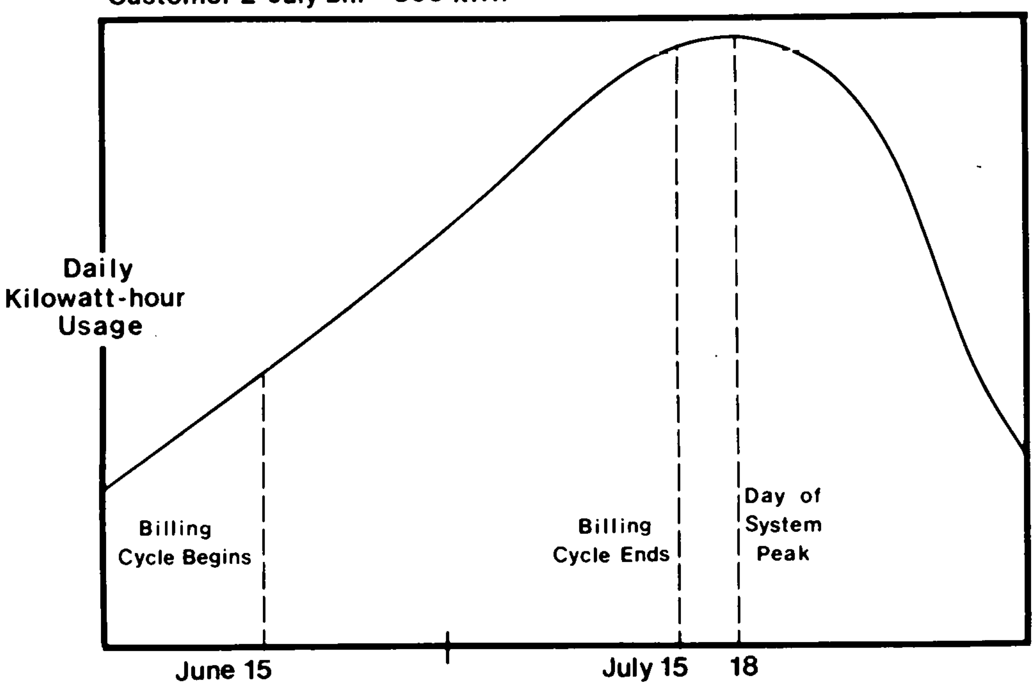


Fig. 2 Problems of Measuring Monthly Kilowatt-Hour Usage with Billing Cycle Data (In the above illustration, the two customers have identical daily kilowatt-hour usages and hourly kilowatt loads. Yet the two have different July bills since they fall into different billing cycles.)

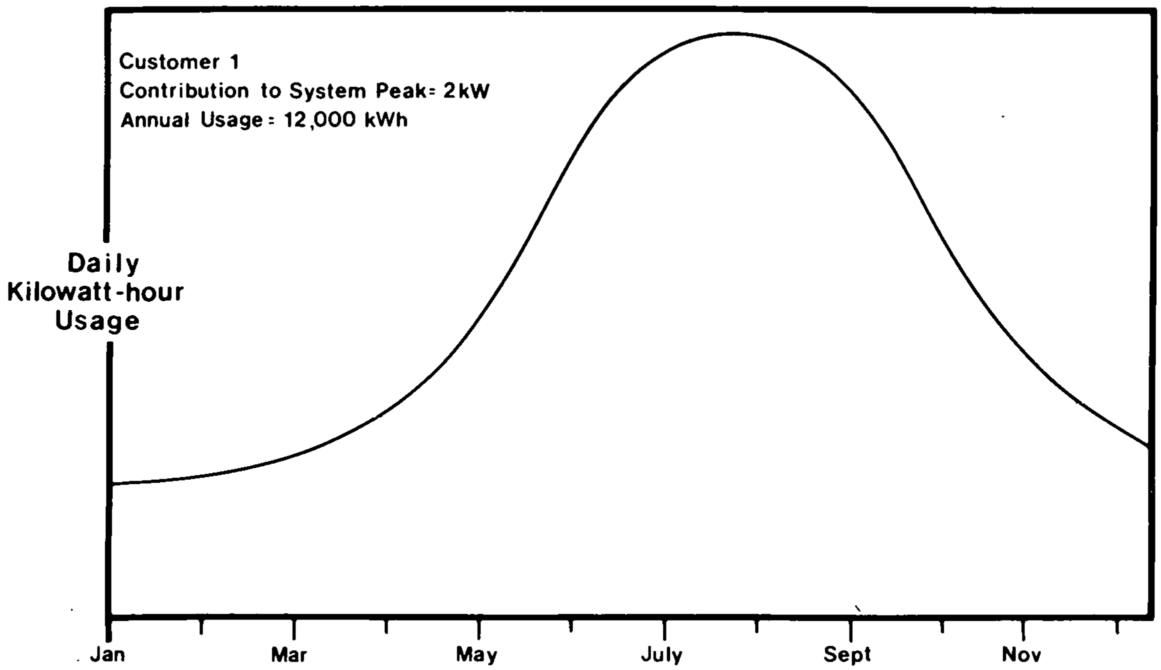
problem here is that annual kilowatt-hours are much less correlated with either customer contribution to system peak or any other instantaneous demand measure. Customers with widely divergent seasonal usage patterns may still have similar totals over the entire year (see Figure 3). For example, a customer with central air conditioning but no electric space heating may use the same amount of electricity over a year as another customer with electric space heating but no air conditioning. But their daily load patterns, whether in summer or winter, will be markedly different, and they should not be placed in the same stratum.

Annual usage data can be most useful to researchers who do not expect widely divergent seasonal usage patterns among their residential customers. Most residential customers in the South have air conditioning while residential customers in some northern regions may have little need for air conditioning. Consequently, wide variations in summer usage by different customers in a particular region would not be expected. Similarly, some service areas have few electric space heating customers and would therefore be less likely to exhibit significant variations in winter usage. Alternatively, it is usually possible to separately stratify the electric space heating customers and it might be possible to separately stratify customers who have air conditioners.

Select Sample from Customers in One Cycle and Stratify by Monthly Kilowatt-Hour Usage. Although this avoids the billing cycle distortions that result from combining customers in different cycles, it presents another possible source of bias: the cycle might not adequately represent the entire customer class. Since companies do not randomly assign customers to billing cycles, it is by no means true that each cycle has the same distribution of demographic and economic characteristics as the entire class does. Therefore, the researcher must confirm which cycles, if any, adequately represent the entire class.

Stratify by an Exogenous Variable other than Kilowatt Demand or Periodic Kilowatt-Hour Sales. To circumvent the unavailability of customer kilowatt demand data and the problems associated with customer kilowatt-hour sales data, other discrete or continuous variables might prove to be useful bases for stratification. Candidates include consumer income, family size, number of rooms in a residence, number of appliances, and the rated capacity of household appliance stock. If a customer class (e.g., residential) includes more than one rate group (e.g., space heating versus general), a very useful stratification procedure is suggested. Some of these variables may be highly correlated with the customer's contribution to the system peak; furthermore, they do not present any billing cycle problems.

However, data for these variables are generally not readily available for the residential population in a specific service area. The costs of ascertaining this information with a two-phase survey may be prohibitive. Those variables that are probably most correlated with customer demand (e.g., rated capacity of household appliance stock) may be especially difficult to ascertain, while others (e.g., family size) might have a far weaker correlation with electricity usage or demand.



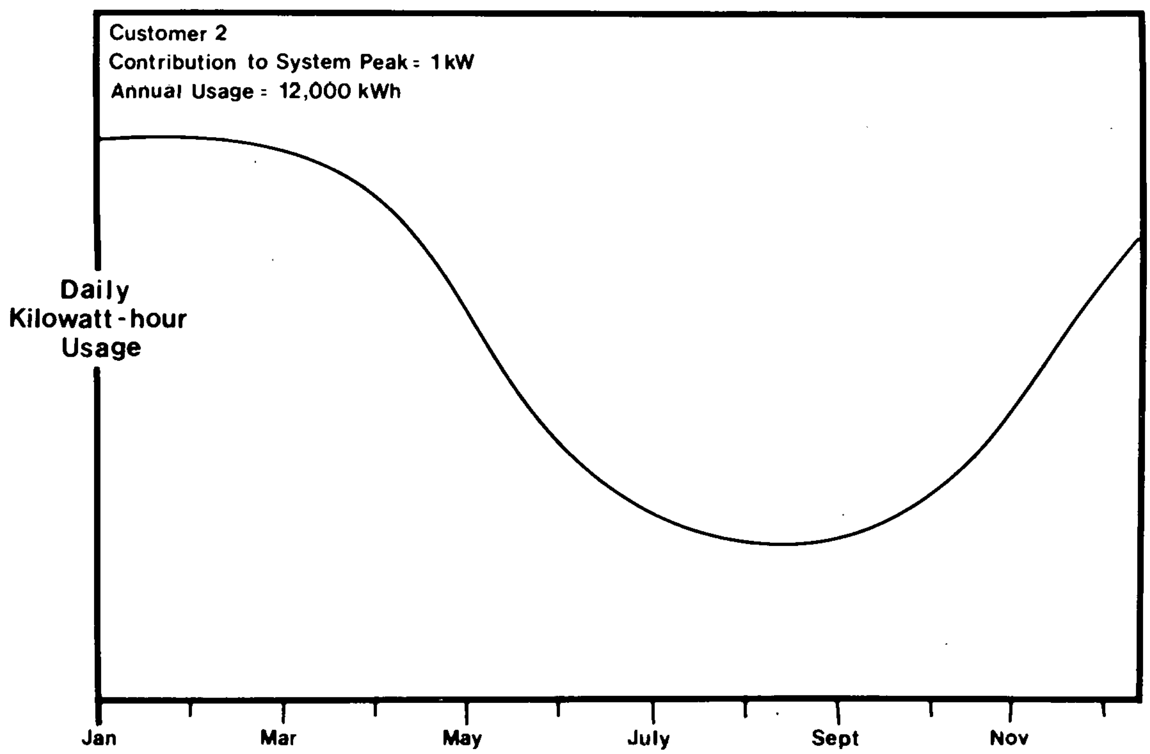


Fig. 3 Problems of Using Annual Kilowatt-Hour Data to Stratify a Load Survey Sample (In the above illustration, Customer 1 owns an air conditioner but does not have electric space heating, while Customer 2 has electric space heating but no air conditioning. Though seasonal variations are great, their total annual kilowatt-hour usages are identical. However, their contributions to system peak demand are not identical.)

Nonetheless, information on customers might be made available with a prior survey. Customer billing records are useful for customer subclasses that have separate rate schedules. Furthermore, if the population is disaggregated into appropriate subclasses with a two-phase sampling framework, each class may be stratified separately on the basis of monthly or annual kilowatt-hour usage or yet another exogenous variable.

Stratify with an Estimated Proxy for Actual Kilowatt Demand. This approach involves using data from previous load research surveys. A linear regression can be estimated between the proxy variable X and the "research variable" Y. A regression basically fits the best linear relationship between Y and X by estimating a and b, where $Y = a + bX$. It is then possible to construct a proxy "Y" for each customer in later surveys simply by forecasting with the estimated linear equation. This proxy can be used to stratify the sample.

Regression techniques also are available for estimating more-complex relationships and nonlinear relationships. In this way, several explanatory variables can be incorporated at once. For example, a more complex relationship may be estimated by adding another exogenous variable Z -- if Z is available historically -- to the regression: $Y = a + bX + cZ$. By obtaining Z and X for future sample customers, a proxy Y can be estimated. (If Y is peak kilowatt demand, X could be kilowatt-hour sales and Z could represent a selected weather parameter at time of peak.) Alternatively, nonlinear relationships may be estimated, such as $Y = a + b(\log X)$ or $Y = a + bX + cX^2$.

The problems inherent with this approach include all those associated with the use of the various exogenous variables discussed above. Using monthly kilowatt-hour data as an exogenous variable raises the billing cycle problem and the problem of the nonrepresentative month; using annual kilowatt-hour data ignores the possibility of widely divergent usage by season. Other exogenous variables may be unavailable, or may be costly or difficult to obtain. Additionally, researchers using this approach face the usual forecasting problems associated with any estimated regression.

However, should the quality of available data be satisfactory, this technique can be quite powerful since it recognizes that several variables can simultaneously affect kilowatt demand. By adding additional exogenous variables to the explanatory regression, a reasonably good explanation of kilowatt demand can be obtained. By the nature of linear regression, the resulting correlation between actual demand and its constructed proxy must be at least as good as the correlation between actual demand and any one included exogenous variable.

Strata Allocation

However the stratifying variable is selected, it is next necessary to allocate the available meters to each stratum. Four procedures are commonly used (other methods are possible as well).

- Treat each stratum as an independent sample and calculate the optimal sample size of each stratum.

- Allocate meters to each stratum by its respective share of the entire population. This is called proportional allocation.
- Allocate meters to each stratum to minimize the overall sample variance. This is termed Neyman optimal allocation.
- Allocate meters to each stratum by a convenient "rule of thumb" that has previously provided a satisfactory breakdown.

The most straightforward procedure for allocating meters across the sample strata is simply to treat each stratum as an independent population and separately optimize its sample size. This might be especially useful in utilitarian frameworks. Therefore, each stratum's optimal size can be estimated with the formulas in Sec. 1.3.4 (this chapter), varying each stratum's estimated standard deviation, confidence, and reliability where appropriate. As a rule, one stratum will have more customers than another if its standard deviation is greater, all else being equal. The same will be true if its confidence level is higher (all else being equal), and/or if its reliability is greater (all else being equal). It is altogether likely that different strata will have different sizes.[29]

If the number of available meters is limited, they could be allocated to the several sample strata in proportion to the strata's optimal sample sizes.[30] For example, suppose 100 meters are available for a three-stratum experiment. Suppose that 400 meters would have been ideal given the desired confidence and reliability: 120 for the first group, 80 for the second, and 200 for the third. One can allocate 30 meters to the first group, 20 to the second, and 50 to the third. It is then possible to use the procedures described in Secs. 1.3.3 and 1.3.4 (this chapter) to evaluate each stratum's resulting confidence and reliability.

Proportional allocation[31] allocates to each stratum, i, a fraction, p_i, of the total sample meters:

$$p_i = n_i/n = N_i/N$$

where:

n_i = number of customers in each sample stratum,

n = number of customers (meters) in sample,

N_i = number of customers in each population stratum, and

N = number of customers in population.

Proportional allocation represents an improvement over nonstratified sampling only when mean usages differ across strata.[32] If this is so, this allocation procedure will enhance the statistical precision of the sample. Furthermore, proportional allocation may be used whether or not the overall sample is optimally sized. That is, if one has a suboptimal number of meters, it is still possible to allocate them proportionately. Problems arise with proportional allocation, as with simple random sampling, if a large fraction of customers are small users.[16]

Neyman optimal allocation (see Appendix B, Sec. B.6, in this volume) attempts to maximize the overall precision of the sample by stratifying the sample on the basis of the number of population customers in each stratum and each stratum's estimated standard deviation(s) in kilowatts.[33] It represents an improvement over proportional allocation only when standard deviations differ across strata. If this is not so, proportional and optimal procedures produce identical results. Optimal allocation may be used whether or not the overall sample is optimally sized.

Neyman procedures can be useful in circumventing the problem inherent in proportional allocation and simple random sampling: the allocation of too few meters to the biggest customers. Since Neyman procedures disproportionately allocate meters in favor of users with the largest variances, and since most researchers feel load variances are directly related to load size, such procedures will allocate meters in favor of large users. However, this procedure might still not rectify completely the possible underrepresentation of large customers.

While Neyman allocation procedures can maximize sample precision when information on standard deviations of customer loads is reliable, it is questionable whether the procedure is useful when such information is constantly changing. These standard deviations are often roughly estimated and are therefore subject to sizable error. If a variable other than load (such as monthly customer sales in kilowatt-hours) is used to stratify the sample, the variance of this variable does not have to differ across strata in the same way that the load variance differs. However, it must vary proportionately to yield valid resulsts ($s^2_{kWh} = as^2_{kW}$, where a is a constant).

Customer loads and their variances can change markedly during the survey. Use of the Neyman procedures might then produce biased results, and it is not clear whether the results would represent improvements over those obtained with simpler procedures. Therefore, Neyman procedures should not be used without careful analysis and the insights of both an experienced load researcher and a sampling statistician.

Some load researchers use "rules of thumb" to allocate meters. Most often, these rules have effected desirable results in prior surveys. A prevalent concern is that mathematical procedures will allocate to some strata too few meters to allow meaningful results for load research; the largest users are sometimes not assured adequate representation. These simple rules might circumvent this problem. Some companies allocate the available meters evenly throughout all strata.[16] Still others allocate meters so that each stratum represents equal total usage (number of meters times average load or sales). Still others select the breakpoints of each strata so that each has 30 meters; this may be necessary to circumvent a nonasymptotic coincidence factor.[34]

While "rules of thumb" might guarantee adequate representation in each stratum, these rules appear to make no systematic effort to enhance sample precision. When a proportional or optimal allocation assigns too few meters to a sample stratum, it is possible to constrain the number of meters in that stratum to a lower limit and recalculate the desired allocation across the remaining strata. Therefore, it is not clear whether "rules of thumb" are valid allocation procedures.

One constraint often incorporated into sample designs is that each stratum must have at least 30 customers. This is because load diversity is not regarded as asymptotic when fewer than 30 customers are sampled. This constraint can be incorporated with any allocation procedure. If any stratum has less than 30 customers, it can be combined with another stratum or constrained to have at least 30. Another possible constraint would set a lower limit on the number and/or fraction of large users in the sample to offset an underrepresentation of these users.

If the resulting size of a stratum exceeds the total number of population customers in that stratum, meters must be reallocated. Any stratum with a population size less than its optimal number of customers should be 100% metered. The remaining strata are then treated as before; the researcher should proceed as though only these strata compose the entire sample. Any allocation procedure should distribute meters across these strata and overall optimal sample size should be calculated for each of these strata.[35]

Strata Breakpoints

In any stratified sample involving a continuous stratifying variable, the researcher must decide how many strata and what strata breakpoints to use. These decisions can be based on subjective or statistical guidelines. Subjective procedures select the number of strata and breakpoints with little regard to statistical theory. Statistical procedures seek to enhance sample precision.

Statistical procedures for choosing the strata breakpoints vary with the allocation method. Optimal breakpoint calculations have been devised for proportional and Neyman allocations. An approximate procedure to be used only with the Neyman allocation has been devised by Dalenius and Hodges (see Appendix B, Sec. B.7, in this volume).[36]

To choose the optimal number of stratum breakpoints, the allocation technique and its corresponding procedure for choosing breakpoints must be selected. Upon doing this, appropriate breakpoints and allocation fractions for a two-stratum sample are calculated.[37] This may be done for a limited or an optimal number of meters. The coefficient of variation can then be calculated. These procedures are repeated for three, four, five, etc., strata. Additional strata should be added until the coefficient of variation no longer decreases substantially. Rarely will the number of strata exceed six. This analysis may be extended to incorporate sampling costs; however, this procedure is beyond the scope of this manual.

Sample Sizing

In determining the overall size of a stratified random sample, the desired reliability and confidence and estimated mean(s) and standard deviation(s) of customer demand(s) must be considered as described in Sec. 1.3.4 (this chapter). In a simple random sample, optimal sample size is determined unambiguously as a function of these three items (and of population size if a finite population correction is warranted). However, when the sample is stratified by any method, the sizing problem becomes considerably more complex. Optimal sample size is now additionally related to individual stratum means, individual stratum variances, and allocation technique. The formulas needed to calculate optimal sample size differ for each allocation technique and change when finite population corrections are made (see Appendix B, Sec. B.8, in this volume).[38]

However, the basic concepts of sample sizing remain unchanged when stratification is introduced. Increased sample size enhances statistical precision. The more reliability and/or confidence one desires, all else being equal, the larger the sample must be. As expected customer standard deviations increase, all else being equal, optimal sample size increases. Allocation procedures that usually reduce overall sample standard deviations reduce the optimal sample size from its simple random sample level.

1.3.6 Randomization Techniques

If the population or stratum customer list is ordered randomly, systematic sampling (see Sec. 1.3.2, this chapter) may be used to produce a randomly ordered list. Alternate sample customers might be chosen in a similar fashion. If the customer ordering is not random, a random number table (such tables may be found in Ref. 39) may be used to select the sample as described below. Recently, computer software has been designed that can generate random numbers.

Table 3 -- which shows only a small part of a random number table -- has (1) a column of consecutive numbers at the left, used for counting purposes, and (2) 50 columns of random digits, displayed in groups of 5 columns for reading convenience. After the population is defined, all customers should be consecutively numbered, starting with 0. The table should then be marked off so that the number of columns corresponds to the number of digits in the population size. (For example, a population with 100-999 members would require the use of three columns in the table.) When the sample size, n, has been determined, the researcher selects from the "subtable" n numbers (formed by combining the appropriate number of columns) that correspond to identifying numbers assigned to customers in the population.

For example, assume that the population size is 250 and that the desired sample size is 25. By starting at the top of the table and using the first three columns of random digits, customers with the identification numbers 139, 207, 19, 124, 128, 137, 40, and 29 would be the first eight sample customers selected; the researcher would continue through the rows of the table until 25 numbers $\leq$ 250 were selected. If the population size is 999 and the desired sample size is 25, a researcher using Table 3 would simply select the 25 random numbers corresponding to the "counting numbers" (left-hand column) 11300 through 11324, and the customers numbered 716, 609, 679, 839, etc. would be chosen for the sample.

1.3.7 Sample Representativeness

Once chosen, the final sample may be checked to see how well it reproduces the relevant characteristics of the population, such as electricity

Table 3 Table of Random Digits

Counting Numbers	Random Digits									
11300	71677	15315	45651	93161	26293	21014	86635	88747	21382	43274
11301	60923	20643	01015	73270	70795	94536	05098	00943	92821	92627
11302	67988	11829	29734	38819	90899	98442	44737	09325	79247	63872
11303	83959	23985	03984	44549	25884	09662	52709	78073	58919	53654
11304	43994	49682	49083	09135	17058	73055	61286	04728	69177	67201
11305	13934	75565	74112	48202	60925	42855	68689	48180	42891	50850
11306	20745	38804	40869	31039	31048	57486	87728	21282	03367	07763
11307	01938	55677	06431	17896	15880	72117	27012	04951	57575	85007
11308	12475	87436	75833	20607	78451	07153	22597	53346	37627	41413
11309	25165	63719	97250	97914	47904	03626	16697	65874	31404	60770
11310	12883	78607	81019	62286	21762	89632	30421	89391	23694	21941
11311	62975	98240	13035	15973	32753	23705	81301	05350	00289	93433
11312	95973	56748	64662	46388	93253	31281	19333	40401	19471	64250
11313	89262	96753	48368	15985	23790	28339	40161	68343	10727	47893
11314	65659	72898	48791	31594	52216	11979	74010	15295	18914	56131
11315	45674	97757	12127	42680	68380	07270	98045	07327	81083	73274
11316	43857	60930	54709	97205	61921	89836	66249	64768	02567	97281
11317	13752	51419	82523	78500	09200	54379	16712	88395	03498	95211
11318	27311	13684	02210	64507	85032	44877	10187	35269	50612	96293
11319	71540	62486	82902	22445	76842	57081	17935	18855	34978	22123
11320	30292	99240	82374	92053	79998	09062	13275	37173	84198	81093
11321	81995	64855	28198	45704	71759	94454	62540	28910	58498	94147
11322	80703	92192	44722	56978	61645	17302	90263	62764	65225	43262
11323	60387	24758	93470	65205	55171	48988	43317	80166	68927	25471
11324	90440	01499	48272	85849	70354	46180	66282	02745	53881	67518
11325	57365	52293	48814	49364	50345	29783	63521	78547	97357	01667
11326	04026	79874	10518	16241	03095	10938	65813	29490	09288	63706
11327	42485	45612	13680	44064	98559	48286	56520	81434	21154	32158
11328	73767	41005	69234	35878	08960	61054	51987	40674	86452	59666
11329	45777	66312	67401	88536	06626	83867	76701	03565	51220	92029
11330	50252	27223	87398	07346	48274	99436	58998	12327	29014	52991
11331	78716	33225	69068	25275	70566	20842	10379	90471	43129	26088
11332	49156	88982	63772	24292	55798	52564	67995	42462	76097	76384
11333	48007	99787	21907	77085	34604	12943	87088	66444	28191	17284
11334	02998	51186	71695	98669	88338	90073	06816	82549	64340	18412
11335	56642	33741	39414	90403	73292	16829	23622	08151	26441	13082
11336	67221	54218	04014	05277	13275	36237	27907	42026	85029	52925
11337	78275	61062	38396	94122	96804	44598	17611	73266	13917	14891
11338	53540	22046	16135	11382	64463	35922	25898	86128	01671	56094
11339	31259	41406	08075	55901	90482	78326	57257	34443	93505	73759

Source: A Million Random Digits, Rand Corp., Free Press, Glencoe, Ill., p. 227 (1955). Used by permission.

usage or demographic characteristics. Information is available from company billing records (which usually have data on rate class, sales, geography, demands, and business codes). Another common procedure for obtaining information on sample customers is to distribute a questionnaire regarding customer demographic characteristics (size of household, number of children, age of members), structural characteristics (number of rooms, insulation, single- or multiple-family dwelling), economic characteristics, appliance holdings and heating source, number of employees, standard industrial classification, and electricity-using processes. (Appendix C of this volume includes the questionnaire used by Carolina Power and Light to survey its residential, commercial and industrial customers.) Once obtained, information about sample customers can be compared with information about population customers. This information is available from customer billing records, prior studies such as appliance saturation surveys, other utility research involving a similar population, and census and annual housing survey information. A chi-square procedure can be used to compare sample and population customers.[7]

1.3.8 Forward Stratification

As noted, sample sizes are usually calculated on the basis of past or present customer variances. Sophisticated load researchers may attempt to size a sample on the basis of expected future customer usage patterns rather than present patterns. This might be especially useful if the project's duration is lengthy and/or the major objectives involve future utility actions. Future customer variances (by stratum type if necessary) must be calculated to stratify the sample and calculate the sample size. Appendix B, Sec. B.4 (this volume), discusses a few procedures for estimating future sample variances.[40]

1.3.9 Concluding Remarks

This discussion on sample design has summarized the process by which reliable statistical estimates of population parameters can be ensured. Sample design generally proceeds as follows (Figure 4 illustrates the interrelationship of these steps):

- Desired reliability and confidence levels are identified. The number of available meters is assessed.
- Researchers choose whether to meter customers in groups or individually. If they choose to meter individual customers, they must select a sampling technique: simple random sampling, stratified random sampling, cluster sampling, or systematic sampling. Two-phase sampling is sometimes necessary if important information on customer attributes is unavailable.
- Whether or not one stratifies a sample, mean(s) and standard deviation(s) of customer demand(s) must be roughly estimated. This is made possible by using historical data from previous studies, appliance surveys, census information, small presurvey samples, and intuition and judgment.

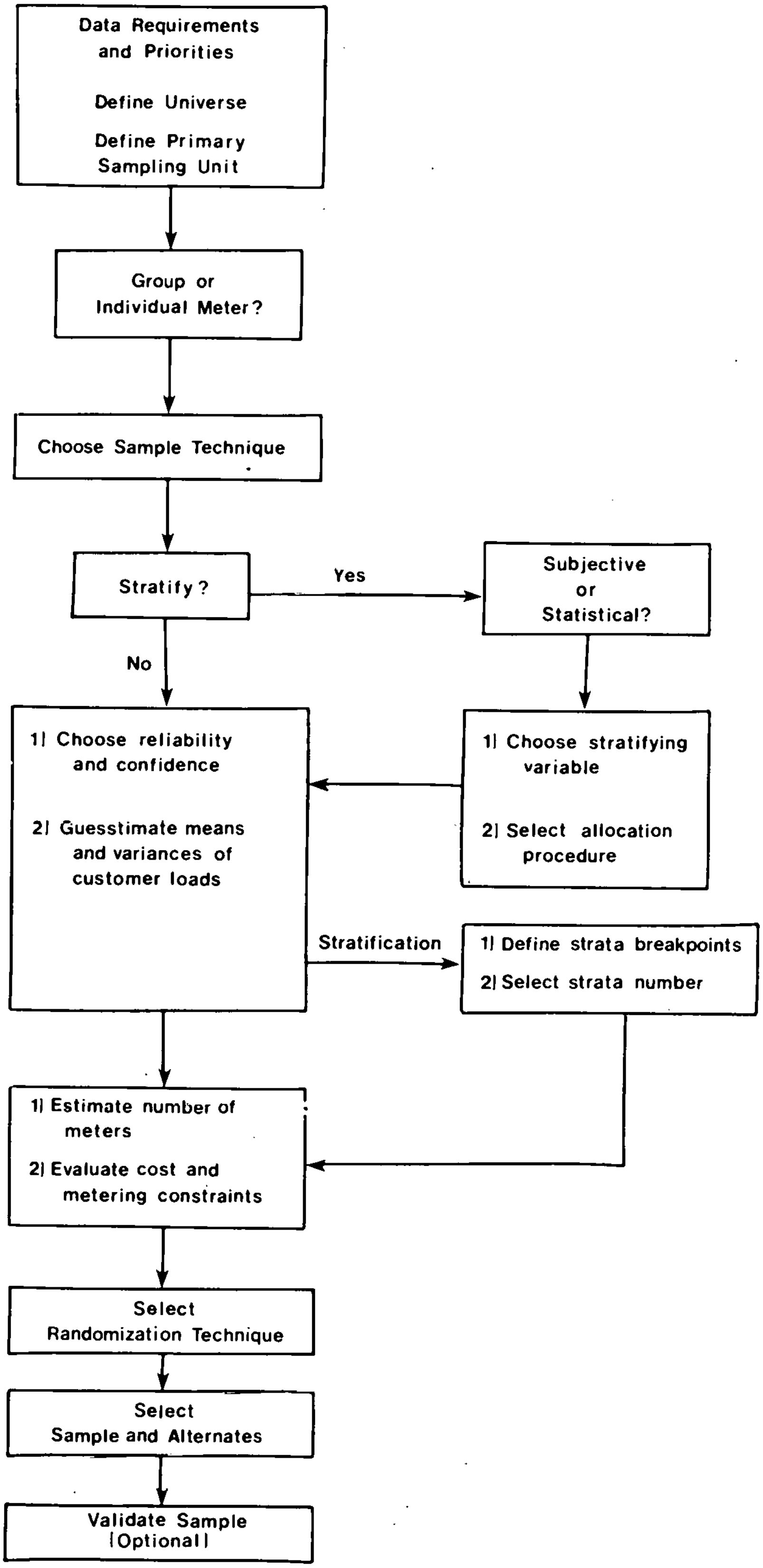


Fig. 4 Sample Design Procedures

- If stratification is warranted, the load research team must select a subjective or a statistical procedure. Five issues require attention:
  - A discrete or continuous stratifying variable must be chosen.
  - An allocation scheme must be selected. The most common procedures include proportional allocation, Neyman optimal allocation, treating each stratum as an independent sample, and several "rules of thumb" that produce satisfactory results.
  - Strata breakpoints must be selected for samples stratified by a continuous variable.
  - The number of strata must be selected.
  - Optimal sample size must be chosen. This is a function of desired reliability and confidence, estimated stratum standard deviations and means, and allocation procedure.
- Researchers must then choose a randomization procedure: selecting every k^{th} customer from a randomly ordered list of customers, selecting customers with a random number table, or generating a random list by computer.
- Upon defining optimal sample size and meter allocation, load researchers may assess whether the sample replicates the relevant characteristics of the population. There are a few ways to "repair" an unrepresentative sample: resample, demonstrate that actual differences are minimal between samples that underrepresent and overrepresent certain customers, or adjust incorrectly sized samples.

1.4 CUSTOMER PARTICIPATION AND EXCLUSION

1.4.1 General Remarks

Primary and alternate sample customers may be randomly selected (within each stratum if necessary). If a primary sample customer cannot be used, the corresponding alternate should replace that customer in the sample. Delinquent customers; chronic complainers; customers in seasonal homes, unsafe homes, or inaccessible locations; small users; or customers with other limiting contingencies may be excluded. However, extreme caution must be exercised when excluding customers because the resulting sample could be unnecessarily biased. Therefore, the possibility of custom-metering troublesome locations might be investigated.

Of the remaining acceptable customers, researchers may decide to secure permission before metering, especially for individual appliance surveys. This might not be legally necessary in all localities and customer load can often be metered from the pole in any case (at greater expense). On the other hand, unwilling customers might not respond to the survey questionnaires.

There are at least five different methods of replacing an excluded primary sample customer:

- Random selection of alternates using the randomization techniques of Sec. 1.3.6 (this chapter).
- Systematic sampling from the universe with two or more random starts. One group is designated as the primary sample, the other(s) as the alternate(s).
- If the original universe ordering is random, choosing the customer adjacent to the primary sample customer.
- Drawing the alternate customer from the same geographic area as the first customer.
- Choosing alternate customers who are similar to the excluded customers. Customers can be compared by demand, kilowatt usage, income, geography, appliance ownership, rate class, or any other reasonable variables.

Pure random replacement (the first three methods) results if a final sample is completely randomly selected. The fourth and fifth methods forego this desirable property in the final sample, but attempt to ensure that no systematic exclusion bias results. In long experiments, customers who leave the sample must be replaced. Any of the above replacement methods can be used for this purpose.

An effort should be made to limit the number of customer refusals. The Association of Electric Illuminating Companies suggests some guidelines for ensuring maximum customer participation:[41]

- In the final selection of customers from the preliminary random sample, avoid those customers whose records indicate poor collections, high bill complaints, and the like. Although the elimination of these customers may slightly bias the results, they should, nevertheless, be avoided.
- Preliminary calls or letters soliciting the customer's aid in making surveys will usually result in a large proportion of "no tests," and therefore should be avoided.
- Make the first visit to the customer's premises an installation visit where this arrangement is possible. Otherwise, explain clearly and arrange for the installation and the expected number of trouble and service visits required.
- The approach to the customer will depend to some extent on the customer's background. The interview should indicate that the test is being made for engineering purposes and requires that the test equipment be installed for a stated period, and that similar tests are made periodically in different neighborhoods in order that the service to all customers might be improved. Oftentimes it is helpful for the installers to have the test equipment with them. When customers, such as those with more education, request

more information, further details may be given them, usually with satisfactory results.

- The testers should be familiar with details of the company's procedure for handling customer complaints, especially appliance repairs, so that they can, if requested by a prospective test customer, handle a complaint to the customer's satisfaction.
- The tester should avoid installations where the conditions of the customer's wiring or equipment are obviously poor and might cause trouble during the test period.
- The company representative should indicate to the customer that the installation and subsequent visits will be made at the customer's convenience.
- The tester should act in a neighborly manner and show an interest in any conversation with the customer. This is desirable since details as to family size, domestic workers, electrical equipment, abnormal conditions, and the like are readily obtained when the customer knows the tester.
- If the customer raises the point as to why he or she was selected, it can be indicated that the choice reflected the customer's good record in payment of bills, regularity in use of energy, and overall appearance from the company's records of being a dependable test location.
- If the customer appears to be opposed to giving permission for the test, no further attempt should be made to persuade him or her otherwise, or to stand upon the legal rights of the company to install special test equipment. The customer selected as the alternate is then substituted.

1.4.2 Questionnaires

Questionnaires are often used to ascertain (when applicable) major appliance ownership, household demographic characteristics (e.g., age and number of members, income), structural characteristics (e.g., number of rooms, age of building, insulation, type of dwelling), employment, standard industrial classification, and electricity using processes. Appendix C (this volume) reproduces the questionnaires that Carolina Power and Light uses in its customer surveys. This sample information can then be compared with data obtained from previous utility surveys, estimated appliance saturations, and the census to investigate the sample's general representativeness of its population. Certain comparisons, such as kilowatt-hour usage, can be made by using information directly from customer billing records.

Ensuring sample customer participation and correct response to survey questionnaires entails careful design. Occasionally, incentives for participation are offered. Procedures for contacting customers and designing the questionnaire must be conceived. Appropriate procedures vary by utility. The advice of a survey expert may be necessary to ensure the best results.

Additionally, some research teams may wish to hire a professional interview staff instead of using utility personnel.

No load research effort will enjoy 100% customer response to its field questionnaires. Nevertheless, researchers should attempt to maximize customer response and avoid any response bias. Nine guidelines have been suggested for questionnaire development:[42]

- Know your population, the topic, and how the population feels about the subject. Word the questionnaire accordingly.
- Use fixed alternatives rather than open-ended questions. For example, rather than asking "what cooking appliances do you own?" one should ask "do you own a range? Is it electric?"
- Make every question count. Do not ask questions to which nearly everyone will respond identically.
- Avoid technical terms. Use terms that make sense to the respondent.
- Start with an interesting, easy, and relevant question to win confidence. Do not start with a personal question, such as one concerning age, income, etc.
- Involve the respondent as a coparticipant in the research enterprise.
- Break the questionnaire into sections.
- Leave room for responses. Do not crowd the questions together to reduce paper costs.
- Avoid hypothetical questions such as "If you had an electric dryer, when would you use it?"

There are three basic ways of contacting customers and presenting the questionnaires: by mail, by phone, and in person. The ideal procedure varies by utility. Factors that affect the decision include personnel availability, travel distances, cost, possibilities for bias, probabilities of response, and the questionnaire's complexity. Table 4 lists the advantages and disadvantages of each procedure. Generally, a combination of telephone and personal contact surveys yields good results.

Questionnaires may be administered by utility personnel or specially hired professional interviewers. The personal administration of the questionnaire is very important and unskilled interviewing may result in inaccurate and incomplete responses. The survey team must be prepared to work nights and weekends since many customers will not be at home during working hours. These two factors would appear to favor a professional survey staff. On the other hand, costs of these staffs may be high and the questionnaire relatively simple. Additionally, company personnel can more easily answer questions regarding utility-related matters.

In some households, more than one person is capable of answering the questionnaire. It is useful to prespecify who is an acceptable respondent.

Table 4 Advantages and Disadvantages of Certain Interviewing Procedures

Contact Method	Advantage	Disadvantage	Conditions for Best Use
Mail	Most economical No special personnel training needed Addresses on billing record	Response rate lowest More attention to questionnaire detail necessary since no personal contact Cannot change order of questions	Cost-constrained utilities Simple questionnaires High-response customers Large service areas
Phone	More economical than by person Better response rate than by mail Order of questions can be strategically varied Good for public relations	Personnel must be trained and/or hired Phone costs Special equipment needed with phone Phone numbers not on billing records, must be looked up Apt to get biased sample since some people do not own phones and others will not be home when called; must keep calling back	Personnel already are available Customer contact is easily effected. Phone ownership is ubiquitous Mail cannot produce high response rate and personal interviews are too costly Large service areas
Person	Personal contact Good response rate Best public relations Order of questions can be strategically varied Might not be so costly since site must be inspected regardless; can do both simultaneously Address on billing records	Travel costs higher More personnel time Personnel must be trained and/or hired Biased sample still possible since customer may not be home	No cost constraints Customers respond poorly to mail questionnaires Small service area Personnel are available Complex questionnaires
Staff	Utility personnel can answer questions Less expensive	Not best interviewing technique	Cost-constrained utilities Simple questionnaires High response rate
Professional interviewers	Professional interviewing	More expensive Cannot answer utility-related questions as well	No cost constraints Complex questionnaires Low response rate

Answers to survey questionnaires could be given, for example, by any adult, the person who pays the bill, or the person whose name is on the bill. Figure 5 displays the details of the customer contact and interview process.

1.5 RECORDING EQUIPMENT SELECTION AND INSTALLATION

1.5.1 Recording Equipment Selection

For a load research project, three major pieces of equipment must be installed for each customer (or group of customers, if group metering is used):

- An energy-use meter to meter electricity usage. This can be either the customer's billing meter or an additional meter. Some researchers prefer replacing the billing meter with a survey meter while others prefer leaving it in. Meters can be single-phase or three-phase.
- A recorder, which records customer demand at prescribed intervals on chart, tape, or solid state memory. There are various types of recorders: General Electric's G-9, General Electric's (and the old Westinghouse R) printometer demand, magnetic tape recorders, solid state equipment, and two-way communications equipment. Demand tapes can be used for billing as well as for load research.
- An electronic or mechanical pulse initiator, which connects the meter and the recorder.

The common recording process works as follows.[43] Customer electricity use is metered; the meter disk rotates at a speed proportional to the rate of energy use. The meter disks are attached to a switch, contact device, or pulse initiator that closes a contact whenever the meter disk completes a prespecified fraction of a revolution. When closed, these contacts complete an electric circuit. The recorder permits the contact closures to be imprinted on recording tape. The ratio of pulses to watt-hours, called the pulse multiplier, is adjustable, and can be varied with the storage capability of the tape. The translated tape is a record of usage per unit of time.

Most companies now use magnetic tape recorders in their load research surveys. (Older recorders, such as G-9 and printometer demand recorders, are still in use but are rapidly falling into disuse since their tapes require manual translation.) Cartridges and cassettes are now in use as well and are making spool tape obsolete.

Tapes have two or four channels, with one channel used to record time intervals, normally in 5-, 15-, 30-, or 60-min periods. The other channel(s) is(are) used to record load data. Four-channel tapes have two additional data channels useful for recording temperature, other appliance usage, Q hours, kilovolt-amperes, or reactive current. In fact, anything that can be metered and transformed into an electronic pulse can be read on a recording tape channel. Meters connected to several different appliances can feed the same

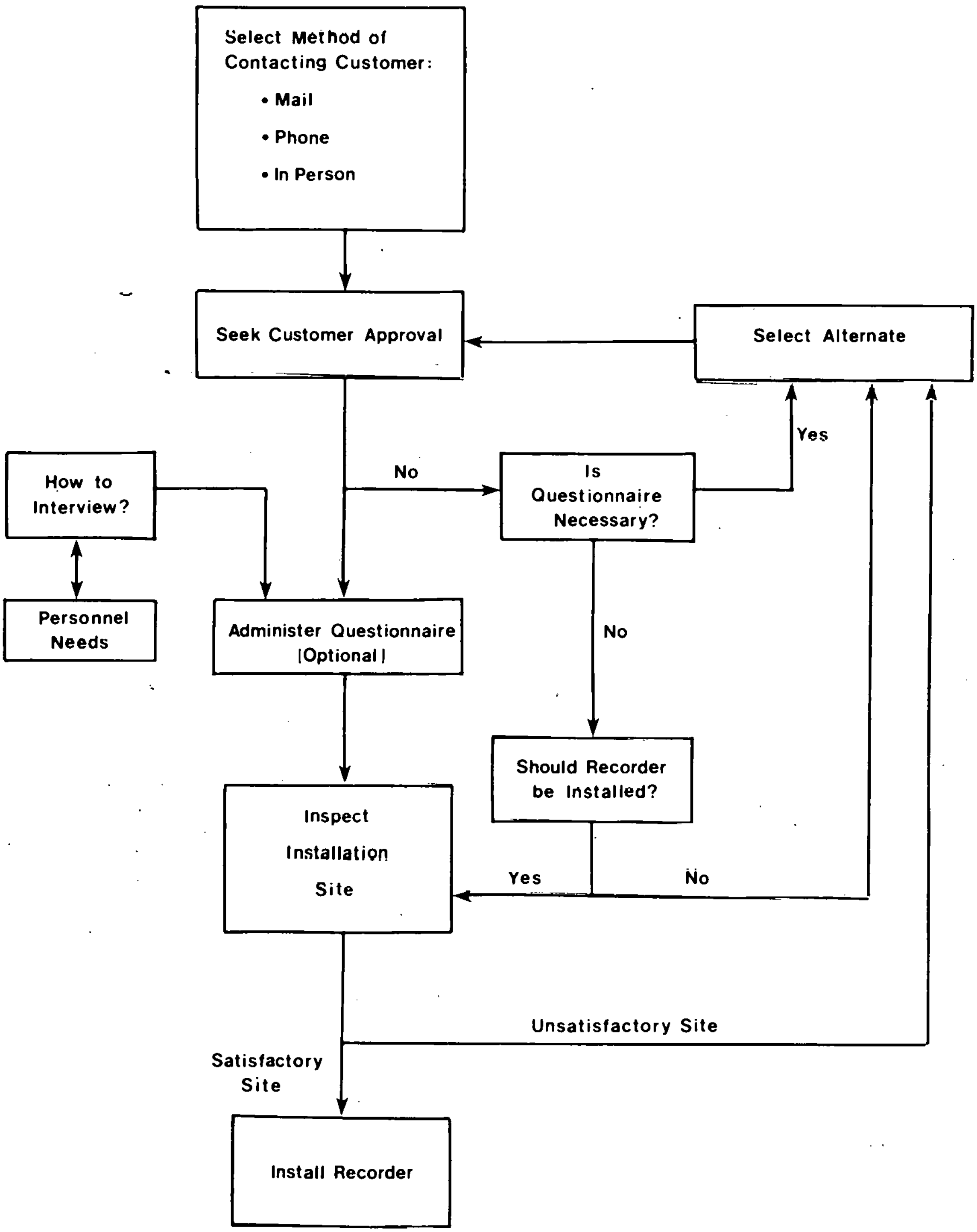


Fig. 5 Securing Customer Participation in a Load Survey

recorder. The total household usage can be recorded on one data channel and usage of specific appliances on the others. Different parts of the same appliance, such as the air conditioner compressor and fan, may be metered separately.

There are four major magnetic tape recorder manufacturers: Westinghouse, General Electric, Sangamo, and Duncan. Each manufacturer makes several models but uses the same basic tape drive. The main differences between any manufacturer's models are modifications such as casing, battery carry-over, etc. Prospective buyers should seek advice from experienced meter teams in other companies.

Magnetic recording tapes are conducive to automatic translation to computer-compatible tapes. The translation process can include collation, assimilation, and editing of data. The translator extracts contact closure points from both the time and the data channels and encodes the data on a computer-compatible magnetic tape (see Sec. 1.6, this chapter). The same manufacturers that produce magnetic tape recorders produce translators. Tapes from one manufacturer's recorder are or can be made compatible with another's translator.

As noted, cassettes and cartridges are rapidly replacing spool tape as the recording medium. Cartridges appear more durable and reliable; cassettes are less expensive. Only spool tape and cartridges have four channels. Prospective buyers should consult more experienced people or manufacturers for recommendations. Each tape can be reused many times, provided it is completely erased before it is reused. Since tape will eventually wear out, a tape verifier, which is a mechanical device for testing whether the tape is still usable, can be obtained. Some translators now can do this job also.

Pulse initiators are activated by the meter disk. As the disk turns, the generated pulses are recorded on magnetic tape. Magnetic tape recorders use two kinds of pulse initiators, mechanical and electronic. An electronic pulse initiator is more expensive but is also more durable and accurate. Only Westinghouse manufactures mechanical pulse initiators.

Since the recorder motors are powered by customer electricity, a power outage will prevent the generation of time pulses. As a result, time pulses on the recording tape are lost and later demand pulses cannot be associated with the proper hour. To circumvent the problem, utilities can use battery carry-overs to keep motors running at a regular speed; these carry-overs can sustain the recorder motors for six to eight hours if a power outage occurs. A power outage beyond the capability of the battery carry-over will still be disruptive. Therefore, a record of all company power outages should still be kept.

Solid state recorders can record customer loads without using recording tape or any moving parts. This avoids many of the mechanical recording problems that result from using magnetic tape. Data are accessible by remote reading, e.g., by phone or a portable reading device. Equipment can be adapted both to display relevant data to the customer and for load control. The data can then be transferred to computer-compatible tape and edited on the company computer, without using any special automatic translation equipment.

Although solid state equipment is currently about 30% more expensive than magnetic tape recorders, its price is expected to fall considerably over the next few years. Costs depend on memory size and load control and display capabilities. Major manufacturers include Robinton, Process Systems, Fairchild, EMAX, Duncan, and Energy Conservation Systems.

Westinghouse, Sangamo, Cutler Hammer, and General Electric market an electronic register (at one-quarter the cost of a solid state recorder). This device can transfer pulses from the meter disk into a solid state memory. These pulses can also be recorded simultaneously on regular magnetic tape. However, the memories in electronic registers can not store hourly demand data; they can store on-peak, off-peak, and mid-peak kilowatt-hour aggregates.

Two-way communications equipment enables pulses to be transmitted through radio signals, telephone lines, or power lines to a remote site where readings can be encoded. Major manufacturers include Rockwell, Westinghouse, American Science and Engineering, and Darcon. These are especially useful when the sample region is sparsely populated and individual meter reading would entail substantial travel time. However, they are not as reliable or as tested as the conventional recorder.

Table 5 summarizes the advantages and disadvantages of different recording equipment and installation procedures. Table 6 displays cost estimates for certain recording equipment. The rest of this section will deal with the most commonly used recording equipment, magnetic tape recorders.

1.5.2 Recorder Installation

Load researchers usually secure their sample customers' permission, especially when individual appliances are to be metered. Metering is usually done at the billing meter location, which can be indoors or outdoors; however, individual appliance metering usually will occur indoors. When load researchers seek to record total usage only, they may circumvent a customer's refusal by installing a recorder at the pole (at greater expense) and correcting for service drop losses. For aggregate customer demand surveys that obtain customer cooperation, the billing meter is often replaced with a survey meter (or a pulse initiator is added to the billing meter). Other times, the billing meter's reading is used to confirm the recording meter and therefore is not removed. When "double metering" is used, an adaptor socket must be installed at additional cost (see Table 6).

Equipment must be installed by skilled meter installers or electrical contractors. Since many research teams attempt to connect the billing meter to the recorder, the same personnel that install the billing meters often install the recorders as well. Should appliances be individually metered, a licensed electrician is often hired if rewiring is necessary. Equipment installation and removal times vary, depending on the complexity of the equipment, necessary rewiring, and travel time. Routine installation jobs take 30-60 min.

Tapes are usually changed every 30-45 days. It takes about five minutes to change a tape, plus travel time. Whoever changes the tape should check for mechanical or electrical malfunctions, clean the recorder heads, and

Table 5 Advantages and Disadvantages of Recording Equipment and Installation Procedures

Equipment, Procedure	Advantages	Disadvantages
Recorders		
G-9	Good for short-term surveys and peak load estimation	Must be manually translated, no longer commonly in use
Printometer demand	Good for short-term surveys and peak load estimation	Must be manually translated, no longer commonly in use
Magnetic tape recorder	Good for measuring around-the-clock usage for any recording interval and survey period, automatically translated, commonly in use	Tape installation and reading subject to error, requires automatic translator, lengthy translation time
Solid state equipment	Good for around-the-clock demand measurement; more reliable than magnetic tape; no need for automatic translator; less translation time; amenable to remote reading, data display, and load control	More expensive than magnetic tape, relatively untested
Two-way communications equipment	Good for around-the-clock demand measurement, lower travel costs	Much more expensive to use, reliability untested
Pulse initiators		
Mechanical	Cheaper	Less reliable and durable
Electronic	More reliable and durable	More expensive
Battery carry-over	Ensures against limited power outage	Additional expense
Media		
Cartridge	Two or four channels, more durable	More expensive
Cassette	Cheaper	Two channels only, less durable
Electronic register	Allows solid state memory recording	Requires additional expense of register and light-emitting-diode tester
Installation practices		
Pole top	Circumvents customer objections, can compare meter readings	Costly to install
Replace or modify	Cheapest, easiest to install, less space-consuming	Cannot compare meter readings
Install alongside existing meter	Can compare meter readings	Must buy adaptor socket, more installation time required, space-consuming
Personnel for tape change		
Billing meter reader	Save on travel cost, experienced meter hand	Has additional responsibilities besides load research meters
Special tape changer	May be more conscientious since this is major responsibility	More travel cost, have to hire and train

accurately record the clock time and date of the tape change. Appendix D (this volume) includes more-detailed tape transfer procedures used by Carolina Power and Light. This appendix is presented for illustrative purposes only, since both survey requirements and meter types vary from study to study. Meter readers or other specially trained field personnel usually change the tapes. Companies experienced in load research indicate that tape changing presents the greatest potential for data loss due to human error. Highly skilled personnel should be used if possible. Whoever performs this function must be prepared for night and weekend work if meters are to be installed indoors.

Table 6 Approximate Catalog Costs of Selected Recording Equipment

Equipment	Cost (1979 $)
Recorders	
Magnetic tape[a]	370
Solid state[b]	600-900
Additional costs of magnetic tape	
Battery carry-over	>70
Four tracks	>130
Electronic register	>150
LED tester	>150
Tapes	
Cassette	15
Cartridge	35
Meters	
Billing meter, single-phase	30
Billing meter, three-phase - no demand register	100
with demand register	160
Pulse initiators	
Mechanical	40
Electronic	125
Adaptor sockets	609
Tape verifier	12,000
Tape eraser	800
Carrying cases	45

[a]Two tracks, no battery carry-over.

[b]Costs vary with memory size and display capabilities.

After a tape is removed, it can be translated, erased, and reused. Since tapes can be used more than once, load researchers usually acquire two tapes per recorder; one is left in the recorder while the other is translated and erased. A few additional spare tapes are also obtained to cover any possible problems.

1.5.3 Problems and Errors

Recorder installation and tape changing offer opportunities for errors that translation procedures should detect later. Cartridges and cassettes can be incorrectly installed and read. The tape changer might incorrectly record meter clock time or billing meter information at the time of tape installation or change. Missing or excess time and demand pulses are a frequent problem. The recording tape might have been taken out too rapidly or too slowly. Mechanical equipment can fail; recorder heads might have been dirty. Reused tapes are occasionally not erased completely; worn or stretched tapes sometimes slip by human inspectors. Where battery carry-over is not used, power outages can be problematical. Even with battery carryover prolonged outages are a problem.

Carolina Power and Light reports that about 25% of its recording tapes have some kind of error.[44] These errors are attributed to: field personnel (4.90%), equipment (6.49%), and other problems (13.27%). The most frequent problems attributed to field personnel were due to recording the wrong times or dates, improper installation or removal of the tapes, incorrect meter readings, and changes on the wrong date. The most frequent equipment problems were due to recorder malfunctions, contacts, recorder drive motors, stacked intervals, and defective tapes or cartridges. The most frequent problems categorized as "other" were due to unknown causes, power outages, incorrect notation of a.m. or p.m. after the hour, and possible wrong start or stop times.

1.5.4 Administrative Aspects

Metering equipment can be controlled by individual departments or by a central administration. A central administration might allow better coordination and avoid excess equipment costs. Under central administration, any department that undertakes a survey will be more likely to understand the entire utility's and other departments' objectives. Consequently, a more relevant survey might be conducted, and the possibilities for cross-departmental data transfer are enhanced. However, if each department has its own equipment, there is no need to worry as much about starting and finishing on schedule.

1.6 ERROR DETECTION AND TAPE TRANSLATION

1.6.1 Tape Translation

Magnetic recording tapes must be translated and the data transferred onto 0.5-in. computer-compatible tapes. These tapes can be read into the company computer for later display and analysis. Translation entails three steps: error detection, editing, and merging. Error detection identifies possible recording errors on the magnetic tape. Editing, which establishes which errors are real and corrects them, can be accomplished automatically on the translator, by the translator operator, or by special data analysis. Merging collates a customer's most recent load record from the recording tape onto the historical records in the company's data base.[45]

The device for translating magnetic recording tapes is an automatic translator. It is run with a minicomputer such as a Hewlett-Packard MX2112A. The tape is pulled at constant speed across the translator's reading head transfers. A translator reads 15-, 30-, or 60- min interval demand pulse counts from the data channels into a demand counter. When it reaches a time pulse on the time channel, it dumps the count into a shift register. The demand counter is then reset and reads the next number of demand pulses until the next time pulse again triggers the shift register.

Translators are expensive, ranging in cost between $50,000 and $150,000. Elaborate translator software packages have been devised to detect and edit errors. Such software can vary considerably in cost and sophistication. Several power companies sometimes share a translator's capital costs. Occasionally, companies will contract with a private firm for tape translation services.

This section provides an overview of the tape translation process (see Figure 6). As most power companies have separate translation and load research departments, a detailed understanding of the translation process is not really necessary for load researchers and is beyond the scope of this manual.

1.6.2 Error Detection

Crucial to any load research project is the ability to discern recording tape errors (see Sec. 1.5.3, in this chapter, for a discussion of several types of errors). Tape errors can be caused by electromechanical failure, tape wear, power outages, or human mistakes. Tapes can be accepted as is, edited and then used, or completely discarded. Translation procedures usually attempt to resolve the following problems.

- Lost time pulses -- failure to detect and correct lost time pulses results in improperly joined demand intervals.
- Excess time pulses -- failure to detect and correct excess time pulses results in improperly broken demand intervals.
- Lost or excess demand pulses lead to a faulty demand count.
- Noncorrespondence of demand pulses to survey meter information -- total kilowatt-hours from the recording tape should correspond to kilowatt-hours information from the survey meter. Discrepancies should be resolved.
- Noncorrespondence of time pulses to reading card information -- reading cards from the recording tape will display time-in and time-out of the tape. The number of recorded time pulses divided by the number of pulses per hour or pulse count (usually 1, 2, or 4) should equal the difference, in hours, between time-in and time-out.
- Power outages -- failure to detect outages can result in misreadings.
- Reading card discrepancies -- information regarding date-in and time-in for any month should correspond to the previous month's date-out and time-out. These all should correspond with the implied times on the tape itself.

Translation equipment can find time pulses on the recording tape. Seven inches on a recording tape usually correspond to one hour. Since tapes should not be changed near expected time pulses, the first time pulse on the tape should not occur right at the beginning of the tape. The translator can total the number of time pulses on the tape. This number, when divided by pulses per hour, should correspond to the difference between time-in and

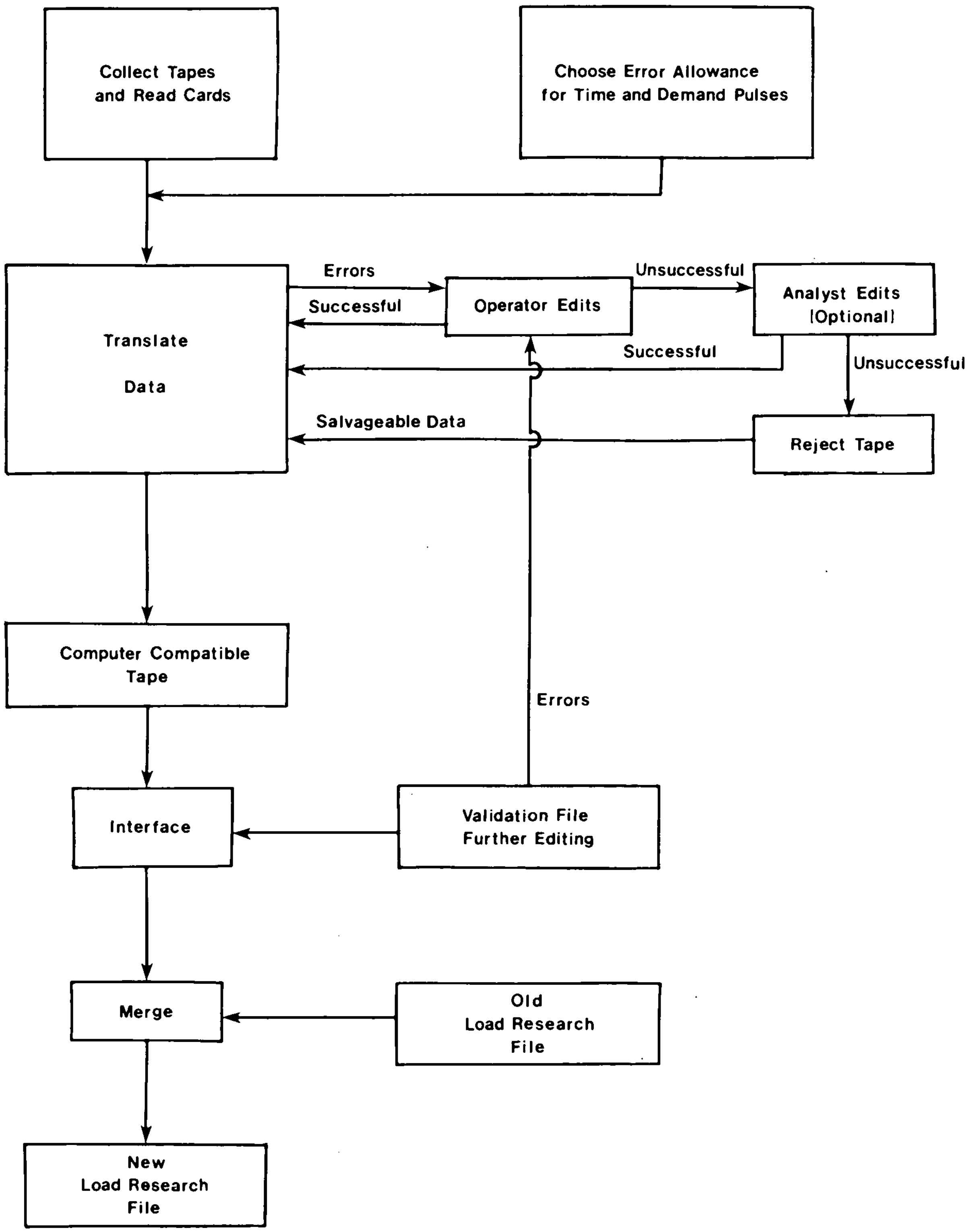


Fig. 6 The Data Translation and Merging Process

time-out, which is available from the reading card. Operators allow a tolerance of a few time pulses, usually no more than one hour's worth.

Depending on the location of the initial time pulse and the tape speed, the translator can next estimate those regions on the tape where later time pulses are ideally expected. The translator locates each "expected region" and inspects the tape for the presence of a time pulse. If no time pulse is found in the region, it is temporarily assumed missing. If a time pulse is found outside of an expected region, it is temporarily assumed excess.

Special problems arise when faulty equipment, power outages, or torque problems (see Sec. 1.5.1, this chapter) throw off the speed of the recorder or break the expected pattern of time pulses. If the translator observes many excess and missing pulses, the problem may have been caused by one of these factors. An effort should be made to recover the tape by incorporating the actual recorder speed and the history of outages.

Lost or excess demand pulses present a less critical problem since external information can be used to make corrections (see Appendix E, this volume). The total number of demand pulses on a recording tape can be divided by the pulse multiplier (pulses/kilowatt-hours) to obtain expected kilowatt-hours; this should approximately equal (plus or minus some small percentage error that must be prespecified) the kilowatt-hour reading on the customer's billing meter. If a discrepancy occurs, the recording tape may be edited or accepted as correct or information on the tape may be changed to correspond to the reading.

After a tape is edited for possible errors, it may be (1) accepted, which means both header information and pulse counts are transferred to storage tape, (2) rejected, which means both header information and pulse counts are removed from the core, or (3) rerun, in which case care should be taken to ensure that the rerun tape is properly handled.

1.6.3 Editing

If a tape is rejected, the operator might then try both to confirm the errors and identify their causes in an attempt to salvage the tape. Particularly troublesome problems might be handled by specialized data analysis. A series of checks can be used:

- In the event of a header-tape discrepancy, the header may be checked for errors.
- The tape can be compared with the customer's previous tapes to examine disturbing load patterns.
- If not done before, header information can be used to confirm the tape's time and demand pulse counts.
- Since recording equipment records over 30-, 45-, or 60-day periods, this information can be used to check for excess or missing time pulses.
- The date-in on the header can be checked against the date-out from the customer's previous tape.

- Power outages might explain differences between "header time" and "tape time." By inspecting the tape, the operator might spot a broken interval that possibly was caused by a power outage and then could calculate when the first outage began by counting previous time pulses and when the last outage ended by counting subsequent time pulses. Some translating equipment now has this automatic capability. Additional information, perhaps from company records, must be used to calculate intermediate outage intervals.

After a suspected error is confirmed, the tape must be edited. For errant time pulses, this means dubbing in missing ones and eliminating excess ones. The entire tape is often discarded if more than a one-hour difference arises between the actual and the expected pulse totals. If time pulses are missing but no location is obvious, one time pulse may be inserted in the middle of the gap, two time pulses one-third and two-thirds through the gap, and three time pulses one-quarter, one-half, and three-quarters through the gap. All insertions should be made at unimportant hours, e.g., 5 a.m. (This is most useful when gaps are few and short.)

Demand pulse discrepancies also can be edited, though many load researchers dislike fabricating data. If demand pulses are edited, header information, the customer's previous tapes, and other customers' contemporary tapes may be used to estimate reasonable demands. (Appendix E, this volume, describes some possible procedures for patching missing data.) After the tape is edited, the operator might assign all modifications status flags. In this way, future analysts can be made aware of the data's editing history. Status flags may indicate corrected time discrepancies, corrected demand discrepancies, false or inserted intervals, corrections for power outages, and any other editing procedures.

After editing has been completed, the recording tape (or intermediate tape, since editing is not always done on the original tape) is translated onto a computer-compatible tape. This tape is eventually run through the main computer and the customer's demand data then become part of the utility's data base.

1.7 DATA STORAGE

A data base has been described as an electric load matrix with the time base along the rows and the sample elements down the columns. Utilities store load research data bases on either disk or computer tape. The most recent data are sometimes stored on disk while previous data are stored on tape. Because of its higher cost, disk is usually a temporary storage medium.

Kilowatt demands are usually recorded in 5-, 15-, 30-, or 60-min intervals. Data may be stored in different intervals, but only in multiples of the recording intervals; i.e., demands recorded in 15-min intervals can be stored in 30- or 60-min intervals but not vice versa. Similarly, data display and analysis can entail different intervals than does storage; analysis can only use the same intervals or larger aggregations of stored data. The objectives of the survey dictate which interval is preferable for storage.

Rate designers concerned about instantaneous peak might prefer 5- or 15-min intervals while marketers concerned about an appliance's general effect on the system load factor might be satisfied with wider intervals. The flexibility of 15-min intervals makes them the most common in current load research. Indeed, Gilbert Associates' survey of storage capabilities in 23 power companies revealed that 18 had 15-min storage capacity (see Vol. 1, Sec. 1.9).[46]

As noted, data may be stored on disk or on tape. Tape is a sequential medium, which means a processor seeking a particular record must sort through all prior records to find the desired record. (This is comparable to a home tape recorder.) Disks allow more flexibility; the processor can find the desired record without searching through every previous record. In addition, it is much easier to add data to a disk; data cannot be added to a tape except at the end, unless some data already on the tape can be erased. However, tape storage is much less expensive. A 2400-ft tape, which costs $10, can store at most 6250 bits per inch, or a total of 180 million bytes. A 50-million-byte disk pack costs $17,000. Because disk storage costs are high, disks are generally used only as a temporary storage medium.

Data can be stored on tapes sequentially or in incomplete sequences. Sequential storage keeps a customer's records together throughout the survey; a customer's new data are merged into the data base following the customer's most recent data. This means that the new data and data from the old tape must be merged onto a new tape whenever new data comes in. Incomplete sequential storage means new data tapes remain separate from previous data tapes. For example, tape storage might be organized by month rather than by customer. This saves money but results in a less organized system.

Tapes can be labeled or unlabeled. There are two common types of labels: the open system of IBM machines and the American National Standard Institute label. Labels include "header" information that identifies the customer and provides summary statistics. Unlabeled tapes are cheaper but much more troublesome to use; only utilities with machines that cannot use labeled tapes should consider the second option.

Data can be stored by pulse or by demand. The amount of space needed to store a number on tape is related to the number of digits in the number; each digit in binary-coded decimal takes up four bits (a bit is the smallest unit of tape storage). For example, the number "1" is written "0001" and the number "9" is "1001." Metering equipment can be designed so that pulse counts on any interval range between 0 and 1000 (see Sec. 1.5.1, this chapter); in a binary representation, these numbers would take up at most nine bits (512 through 1023 are nine-digit numbers in the binary format). As customer usage increases over time, pulse multipliers can be varied to maintain compatibility with this nine-digit format. Since eight bits compose a byte in most computer systems, at most two bytes are usually needed per pulse number. Demand numbers can have considerably more digits, and storage costs can be much greater. However, reading data from the tape is much easier when the data are stored by demand, kilovolt-amperes, degrees Fahrenheit, etc. Converting pulse readings to demand readings entails significant central processor costs. Of the 23 companies Gilbert Associates surveyed, 13 stored data by pulse and 10 by kilowatt demand.[46]

Demographic and weather data can be stored on tape but it appears that this is not usual. Of the companies surveyed by Gilbert Associates, 20 gathered demographic data but only 8 stored them, and 18 gathered weather data but only 3 stored them.[46] Companies can always store these data on paper.

1.8 DATA DISPLAY AND ANALYSIS

Data display and analysis involve parameter estimation, statistical analysis, and extrapolation to class and system demand estimates. Several computer software packages may be purchased for data display and analysis. The specific procedures for display and analysis of the sample data depend on the survey's objectives. Analysis and display capabilities should be flexible enough to permit interdepartmental data transfer and programming modifications and additions.

The following issues in data display and analysis are discussed below:

- What data are displayed, what classes and strata are displayed, and what are the usual intervals of display?
- What statistics do display plots and tables usually present?
- What statistical techniques are useful in data analysis?
- What are the methods of extrapolating from sample data to obtain aggregate class demand information? What about aggregate system demand information?

The ensuing discussion presents detailed technical procedures for data display and analysis and develops statistical procedures where relevant. A reader interested in a general overview is referred to Vol. 1, Sec. 1.8.

1.8.1 Statistics and Domains of Analysis

Most load data are recorded and stored in 15-min intervals, although 30- and 60-min intervals are not uncommon. Data are frequently displayed and analyzed in different intervals than those in which they are stored. The reporting interval length depends on the purposes of the study. The rate department might need 15-min demand intervals to measure various peak demands, but the marketing and system design departments might find 30- or 60-min intervals satisfactory. However, only upward aggregations of demand data are possible.

Both graphs and tables are used to display data. Among the most useful and the most frequent exhibits are the following:

1. Individual or average customer demand at the hour of the:
   a. Customer monthly, seasonal, or annual peak
   b. Class monthly, seasonal, or annual peak
   c. System monthly, seasonal, or annual peak

2. Demand by individual appliance for 1a, 1b, 1c, and the hour of the appliance's monthly, seasonal, or annual peak
3. Individual or average customer demand by time-of-day:
   a. For the day of customer monthly, seasonal, or annual peak
   b. For the day of class monthly, seasonal, or annual peak
   c. For the day of system monthly, seasonal, or annual peak
   d. For average day, weekday, and weekend day defined by month or season
4. Demand by an individual appliance for 3a, 3b, 3c and 3d
5. Customer diversity or coincidence factors in relation to class usage, system usage, and number of customers
6. Energy usage by appliance, customer, class, or system; by day, month, or year; often adjusted for weather discomfort

The data can be extrapolated (see Sec. 1.8.3, this chapter) to class estimates, such as:

- Class demand at hour of:
  - Class monthly, seasonal, or annual peak
  - System monthly, seasonal, or annual peak
- Class demand by time-of-day for the:
  - Day of class monthly, seasonal, or annual peak
  - Day of system monthly, seasonal, or annual peak
  - Average day, weekday, and weekend day defined by month or season
- Class diversity or coincidence factors
- Total class usage by day, month, or year, often adjusted for weather discomfort

Finally, class load information can be aggregated to estimate total system loads:

- Peak or time-of-day demand on day of system monthly, seasonal, or annual peak
- Peak or time-of-day demand for average day, weekday, and weekend day defined by month or season
- Total system usage by day, month, or year, often adjusted for weather discomfort

One may calculate standard errors along with any estimated demand or usage parameter. In addition, several modifications, such as analysis by day of week, are possible. Average peak-day load curves may be obtained by averaging the five or ten days with the highest peak load or the most uncomfortable weather; each season could be handled separately. Demographic and coincident weather data can be presented along with demand data. Appendix A (this volume) contains the data format used in AEIC annual reports.

Data can be analyzed by class or subclass. Domains of analysis are nonoverlapping subgroups of a population that together compose the entire population and that serve as the organizing framework for analyzing the data. (Strata have been defined as nonoverlapping subgroups of a population that together compose the entire population and that serve as the organizing framework for designing the sample.) It is not necessary that the domains of analysis and the sample strata be identical. They may differ in number or in breakpoints.[47]

Usually, data will be analyzed by the same classes that were used to design the sample. A discrete variable that served as a basis for stratification will usually serve as a basis for analysis. Researchers must decide where to put those customers who were selected because they fell into one class or stratum and who moved to another during the survey; this is the "switching" or strata stability problem. This decision hinges on whether the customer's observed switch is felt to reflect a long-term change or a short-term aberration.

Samples stratified on the basis of a continuous variable frequently use different strata and domains of analysis. The domains can be structured along subjective or statistical guidelines. If new domains are defined, a stratifying variable, strata breakpoints, and the number of strata must be selected. It seems that actual kilowatt load may be a viable choice for a stratifying variable, but kilowatt-hours might also be used. Domain breakpoints and number can be selected along subjective or utilitarian guidelines. The stratifying variable, breakpoints, and number of strata can vary monthly; it may be especially worthwhile to adjust breakpoints since loads and usage vary seasonally. Because it is not necessary to use the same variable(s) to design the sample and to analyze the results, actual customer kilowatt loads can be used to define the domains. If new domains have not been defined, the "switching" problem must still be addressed.

The "switching" problem becomes even more troublesome when the same sample serves as the basis of several periodic reports; for example, the survey may last a year, but results are reported quarterly. A customer selected for inclusion in one stratum may demonstrate different usage in each quarter. To locate the customer in any domain merely on the basis of usage in the present quarter ignores the possibility that usage in the quarter does not reflect long-term patterns. Accordingly, this scheme would underestimate the dispersal of customer loads in each stratum. Perhaps in this case, customers should be analyzed in their original stratum until the survey is completed.[48]

1.8.2 Statistical Analysis

Appendix B, Sec. B.1 (this volume), includes a technical discussion of many important statistical terms useful to data analysis. The reader should review that appendix if the following discussion proves too technical.

Statistics can be derived for each domain of analysis. Unless the original sample was a simple random or stratified sample with a proportional allocation, the simple formulas of Appendix B, Sec. B.1, will usually not be suitable for measuring expected values and variances relevant to the population domain. This is because each domain of analysis rarely will include customers from only one stratum. Customers from different strata will have different probabilities of selection (unless the sample was simple random or proportionately stratified). However, the formulas of Appendix B, Sec. B.1, assume each customer to have equal probabilities of selection. Therefore, a correct calculation of statistics specific to one domain must correct for the fact that the customers in the domain can have unequal chances of selection that depend on the stratum from which they were selected. (If all customers in a domain were selected in the same stratum, no complication arises.)

For example, suppose that a survey had been designed with two strata -- customers using more and less than 500 kWh/month -- and is to be analyzed similarly. After the survey, it was found that several customers had migrated across strata. Then four customer types existed:

- Customers who used less than 500 kWh/month prior to and during the survey
- Customers who used more than 500 kWh/month prior to and during the survey
- Customers who used less than 500 kWh/month prior to the survey but more than 500 kWh/month during the survey
- Customers who used more than 500 kWh/month prior to the survey but less than 500 kWh/month during the survey

Unless proportional allocation was used, customers in the low-use stratum (<500 kWh/month) had a different probability of selection than customers in the high-use stratum (>500 kWh/month). Therefore, estimated sample means and variances of the loads in each post-sample domain must incorporate the fact that the domain comprises two types of customers who had different probabilities of selection. Procedures for modifying the equations entail complex mathematical formulations and require the advice of a statistician.

To circumvent this problem, sample customers are sometimes maintained and analyzed in their original presurvey strata without regard to usage during the survey. Since all customers in a stratum have identical chances of selection (assuming the members of the stratum were randomly selected), mean and variance estimation is relatively simple. However, this approach ignores the information about customer loads obtained in the survey and assumes that the presurvey data on each customer better represent the customer's long-term usage than do the more recent survey data. Additionally, researchers may wish to use the survey's results to estimate standard deviations for the next survey. Unless the original strata are at some point replaced, they will serve as an organizing framework years after their original use. Therefore, it seems that better resolutions are possible with the advice of a statistician.

Once sample means and variances are obtained, simple hypothesis tests may be formulated to consider whether any mean $\overline{X}$ is equal to a particular value m (such as a test of $\overline{X} = 5.43$). Tests may be formulated to consider whether $\overline{X}_i = \overline{X}_j$ for different domains i and j. Further hypothesis testing can simultaneously evaluate composite hypotheses of the form $\overline{X}_1 = m_1$, $\overline{X}_2 = m_2$, ..., $\overline{X}_i = m_i$, or composite hypotheses of the form $\overline{X}_1 = \overline{X}_2$, $\overline{X}_2 = \overline{X}_3$,

$\overline{X}_3 = \overline{X}_4, \ldots, \overline{X}_{i-1} = \overline{X}_i$. Finally, one may test the sample variance(s): $s_2 =$ K where K is a constant or $s_i^2 = s_j^2$ for domains i and j.*

The construction of confidence intervals is related to hypothesis testing. An estimated $\overline{X}$ will rarely precisely equal its expected value m. By using the properties of the central limit theorem, the distribution of $\overline{X}$ around m may be calculated. Accordingly, bandwidths may be calculated and the probability deduced that the actual m falls within a certain range of $\overline{X}$.*

Linear regression techniques can estimate a linear relationship between a dependent variable, e.g., kilowatt demand, and independent variables, e.g., kilowatt-hours, weather, or electricity price:

$$Y = a + b_1X_1 + b_2X_2 + \ldots + b_iX_i$$

where:

Y = dependent variable,

X_i = independent variable i, and

$a, b_1, b_2, \ldots, b_i$ are coefficients.

If i + 1 observations are available for the Y and X values, the i + 1 coefficients can be exactly determined. (If less than i + 1 observations are available, it is impossible to calculate a linear relationship at all.) If there are more than i + 1 observations, which is probable, it is highly unlikely that all the points will lie on one line. Linear regression procedures calculate the line that comes as close as possible to running through all the data points that represent the observations. This line is obtained by choosing coefficients to minimize the sum of squared errors, SSE:**

$$SSE = \sum_t (Y_t - a - b_iX_{it} - b_2X_{2t} - \ldots - b_iX_{it})^2$$

where t = observation number.

1.8.3 Extrapolation

While research into individual customer and stratum loads is useful, its relevance is enhanced when these data are extrapolated to estimate class or system loads. There are several procedures for extrapolating from sample data to class and system load estimates. One approach provides estimates for each domain of expected hourly demand per sample customer (see preceding section for an important caution about calculating these values). These estimates are multiplied by the total number of population customers in the domain. Upon summing across all strata in a class, corresponding class loads can be estimated. Class loads can further be summed to estimate system loads,

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*Any elementary statistics textbook can provide more detail; see the bibliography in this volume.

**Any elementary statistics or econometrics textbook can provide more detail; see the bibliography in this volume.

first correcting for line and transformer losses. Losses can be estimated by the company's engineering department.

A second procedure begins by calculating, for each domain, j, the sum of the customer's loads for each hour, h. This sum is expressed as:

$$X_{hj} = \sum_{i=1}^{n_j} X_{hij}$$

where:

X = hourly kilowatt demand (for hour h, customer i, domain j), and

n_j = number of customers in domain j.

These numbers are in turn multiplied by the ratio r_j, which is defined for each domain as:

$$r_j = kWh_j^p / kWh_j^s$$

where:

kWh_j^p = kilowatt-hours consumed by all population customers in domain j, and

kWh_j^s = kilowatt-hours consumed by all sample customers in domain j.

The fundamental difference between the two approaches is that they use two different bases for extrapolation. The second approach allows for the possibility that usage per population customer can differ from usage per sample customer, which is an advantage.

However, population kilowatt-hour usage should be measured over the same interval as sample kilowatt-hour usage. Monthly population kilowatt-hour sales are measured across several billing cycles and therefore cannot be measured over the same interval as monthly sample kilowatt-hour usage. Using annual population kilowatt-hour sales may circumvent some billing cycle problems, but this approach does not allow for the possibility of monthly fluctuations in r_j. Additionally, the r_j approach will produce a biased extrapolation. Therefore, its use warrants the attention of both a sampling statistician and an experienced load researcher.

A possible way of avoiding the kilowatt-hour measurement problem is to carefully adapt kilowatt-hour usage in one billing cycle. There are several billing cycles in any month. Though each may exhibit a different customer mix, some may have a customer breakdown fairly similar to that of the population at large. These billing cycles can be termed representative. By multiplying average kilowatt-hour usage per customer in a representative cycle by the number of customers in the population, one may estimate the total kilowatt-hour usage that would result had all population customers been billed on that cycle. This total can be distributed over the cycle's billing distribution; thus, kWh_j^p can be obtained for each domain j.

To obtain appropriate kWh_j^s values, it is essential that these be measured over precisely the same interval as the representative cycle. That is, for each domain j, kWh_j^s is defined as the total customer usage between the beginning and the end of the representative cycle. From here, r_j is easily calculated and hourly loads in each domain j can be extrapolated.[16]

If data are to be extrapolated to an entire class or population in a different year, the extrapolation procedure must allow for the difference. For example, in a customer-based extrapolation, one would obtain an estimated total for year T by multiplying expected hourly demand per customer in year t, X_t, by the expected number of population customers in year T, N_T. It is then possible to extrapolate sample statistics obtained over different years to a common-year estimate.

1.9 ORGANIZATION AND MANAGEMENT

Since load research is pursued for many reasons, a load research department that interacts well with other departments in the company will produce the most useful results (see Secs. 1.2.1 and 1.2.2 of this chapter and Sec. 2.9 of this volume). The load research department should interact with the system design, load forecasting, cost-of-service, rate design, marketing, and new technologies departments, which will in turn interact with each other. Additionally, since the load research department depends on the metering, translation, and computer divisions, effective interfaces are necessary with each (see Figure 7). Lack of adequate interaction in any area

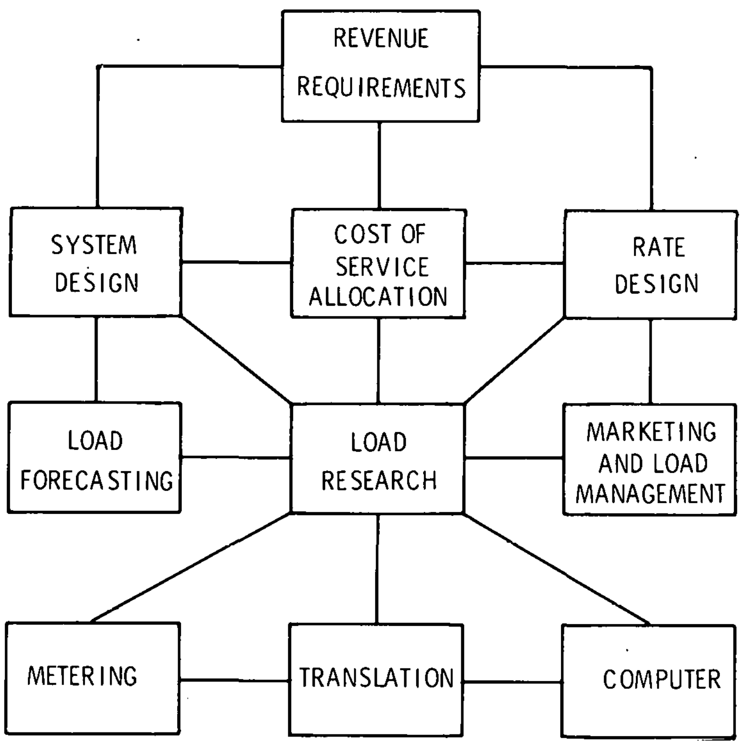

Fig. 7 Organization of Load Research Activities

of load research endangers the smooth implementation of load research programs. Top management supervision and commitment are essential to an efficient program.

1.10 ESTIMATED COSTS OF LOAD RESEARCH

Tables 7 and 8 display the estimated costs of load research. They are only illustrative since each expense is affected by many factors. Costs can be divided into fixed costs and operating expenses. Fixed costs include those necessary to begin a load research survey; once paid, they do not vary over the duration of the survey although some fixed costs vary with the number of sample customers. Operating expenses vary with the number of sample customers and the duration of the experiment.

Fixed costs include, among other components, the capital cost of equipment and software development expenses. Equipment costs include the costs of a translator, load survey recorders, a magnetic tape eraser, a tape verifer, and carrying cases for the meters. Translator and meter costs may vary considerably, depending on the sophistication of the equipment. Costs displayed in Tables 7 and 8 apply to one particular set of equipment only and must be modified for different choices of equipment. Software development incorporates the costs of translation, storage, and display programs. Estimated "in house" development time for all three components is 18 months. After deriving equipment and software development costs, it is necessary to annualize the total to compare it with variable costs. A 20% fixed charge rate has been assumed.

Total fixed costs are the sum of annualized equipment and software expenses, sample selection costs, analysis expenses, and the training costs of metering and marketing personnel. Sample selection costs vary considerably depending on the questionnaire, the method of interview, the response rate, and the survey staff. The figures displayed in the table are considered above average. Analysis of survey results and report writing can be as extensive as necessary, so the costs in Table 7 are only illustrative. Training costs vary considerably with the number and the experience of a utility's metering and marketing personnel.

Operating expenses include the costs of actually implementing the survey. They vary with both the number of customers and the duration of the survey. One-time operating expenses include meter installation and removal and the survey of the customers' premises. Each can vary since large customers may require more-extensive procedures. Continual operating expenses include the labor and transportation costs involved in changing tapes; transportation costs vary with distances required to be traveled. Translation, editing, storage, analysis, and miscellaneous costs depend on the complexity of the procedures that are followed.

The total costs of a 12-month load research survey of 100 customers are estimated in Table 7 at $138,480. As noted, costs vary both with duration and with the number of customers. Table 8 demonstrates how costs may change in response to additional customers and longer surveys. It is interesting to note that 2400 customer-months of data can cost from $186,000 to $193,000, depending on the customer/month relationship. Similarly, 3600 customer-months

Table 7 Estimated Costs of Load Research (1979 dollars)

FIXED COSTS (for 100 recorders)		
<u>Equipment</u>		
Magnetic tape translator (price depends on sophistication)	$100,000	
Magnetic tape load survey recorders		
two-track tape, no battery carry-over ($370)		
with battery carry-over ($70)		
electronic pulse initiator ($150)		
single-phase meter ($30)		
spare cartridge ($35)		
total recorder system ($655)		
cost of 100 recorders	65,500	
Magnetic tape eraser	800	
Tape verifier	12,000	
Metal carrying cases (20 at $45 each)	900	
Total cost (100 recorders)	$179,200	
Annualized cost: $179,200 (total cost) × 20% fixed charge rate		$35,840
<u>Software development</u>		
Annualized cost: $75,000 (total cost) × 20% fixed charge rate		$15,000
<u>Initial sample selection and prestudy office work; including computer time and consulting costs</u>		$15,000
<u>Analysis of results and report writing</u>		
300 man-hours × $20/man-hour × 2 (for 100% overhead)		$12,000
<u>Training sessions for meter and marketing personnel</u>		$3,000
TOTAL FIXED COSTS (for 100 recorders)		*$80,840*
OPERATING EXPENSES (C = no. customers, M = no. months in survey)		
<u>One-time costs</u>		
Installation and removal of meters: 1.5 man-hours/visit × 2 visits/customer × $10/man-hour × 2 (for 100% overhead) × C customers		$60C
Survey of customer premises: $10/customer × C customers		$10C
<u>Continual costs</u>		
Labor for tape changing: 1 man-hour/visit × $8/man-hour × 2 (100% overhead) × C customers × M visits		$16CM
Transportation for tape changing: $1/visit × C customers × (M+2) trips		$C(M+2)

Table 7 (Cont'd)

Translation	
Data translation: \$10/man-hour × 1 man-hour/run × 2 (100% overhead) × C customers × M months	\$20CM
Translator	\$1,800
Editing data, creating data bank, computer analysis of results	
0.1 hour/run × \$240/hour × 2 runs/data bank × 0.025C data banks (customers ÷ 40) × M months	\$1.2CM
Other	
Routine maintenance, auxiliary equipment: \$150/month × M months	\$150M
Incremental maintenance of recorders, extra tape, etc: \$10/customer × C customers	\$10C
TOTAL OPERATING EXPENSES	
General case	*\$(1800 + 82C + 150M + 38.2CM)*
For 12-month survey of 100 customers	*\$45,640*
TOTAL FIXED PLUS OPERATING COSTS	
General case	\$(82,640 + 82C + 150M + 38.2CM)
For 12-month survey of 100 customers	\$138,480

Source: This table combines estimates made in two documents -- (1) Rate Design Study: Load Research, prepared by Gilbert Associates for the Electric Utility Rate Design Study, Exhibit 14 (1979), and (2) Proc. Load Research Seminar, Association of Edison Illuminating Companies, Chapter 7 (July 1979). Estimates sometimes differed and appropriate compromises and resolutions were required.

Table 8 Comparative Costs of Load Research

No. of Sampled Customers	Cost (\$) for Various Survey Periods				
	12 months	18 months	24 months	30 months	36 months
100	138,480	162,300	186,120	209,940	233,760
200	192,520	239,260	286,000	332,740	379,480
300	246,560	316,220	385,880	455,540	525,200

of data can cost from \$233,000 to \$247,000. It is obvious that, whenever possible and valid, additional data should be obtained by stretching the duration of the survey rather than by adding customers.

1.11 ESTIMATED TIMETABLE FOR LOAD RESEARCH

Figure 8 displays two schedules useful in suggesting likely time requirements for certain load research procedures.[49] However the times shown in the figure for each task are not explicit and could vary depending on the personnel's previous experience in every facet of the program. New load research teams should begin to consider equipment and software purchases and programming costs at least one year before the start of the survey. Therefore, they should allow for maximum flexibility in any equipment purchase since implementation will not be immediate. Sample design may take as little as two months, but additional time should be allocated if two-phase sampling (see Sec. 1.3.2, this chapter) is to be used. Meter installation might also entail more time if elaborate customer interviewing procedures are used.

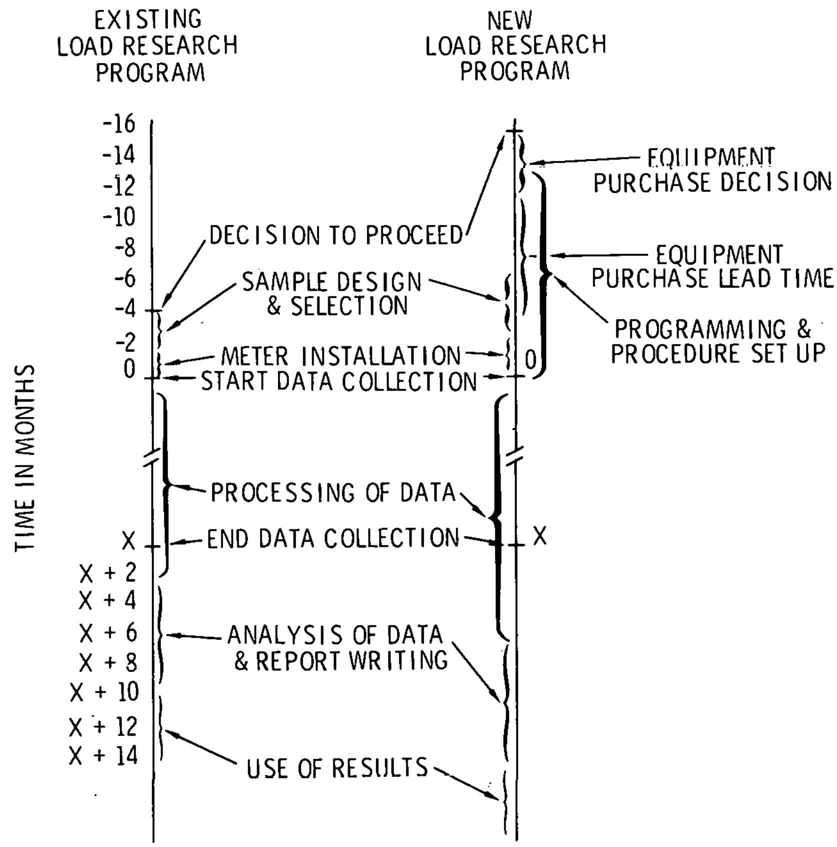

Fig. 8 Load Research Timetable (adapted from paper by C.T. Loshing, Cleveland Electric Illuminating Co., presented at AEIC Load Research Committee Load Research Seminar, Philadelphia, July 1979)

Similarly, analysis of data and report writing can take different amounts of time, depending on the extent of the study.

1.12 CONCLUDING REMARKS

When implementing the procedures described in this chapter, load researchers must be cautious to temper theory with judgment and experience. This chapter is best approached as a discussion of suggested guidelines rather than as a prescription of rigid rules. First and foremost, load researchers must specify their objectives and evaluate their cost constraints before undertaking any purchases or implementing any procedure.

Load researchers in general might consider the advice of more experienced practitioners from other utilities, consultants, academicians, professional statisticians, professional interview staffs, and equipment manufacturers. Research teams unfamiliar or uncomfortable with mathematics should hire an in-house statistician or a statistical consultant; sample design is not a straightforward process and warrants a well-trained specialist. Similarly, substantial errors can be made in customer interviewing, and additional professional advice can be useful here. A load research project should be capably administered to ensure that the advice of highly paid technical specialists is being taken in the best interests of the company.

2 ONGOING LOAD RESEARCH PROGRAMS AT THREE UTILITIES

2.1 INTRODUCTION

This chapter discusses and compares load research conducted by three major electric utilities: Carolina Power and Light Company (CP&L), Long Island Lighting Company (LILCO), and Southern California Edison Company (SoCal). These three utilities were surveyed because their load research programs are based on relatively sophisticated methodologies. To clarify the discussion and comparison of the three load research programs, this chapter is organized in the same fashion as Chapter 1 of this volume (and of Vol. 1), with the following sections:

- Data requirements and priorities
- Sample design
- Customer participation and exclusion
- Recording equipment selection and installation
- Error detection and tape translation
- Data storage
- Data display and analysis
- Organization and management

The information presented here is based on a questionnaire completed by load researchers at the three utilities as well as on telephone interviews conducted with them. Appendix F (this volume) contains the questionnaire and supplemental interview questions and summarizes company responses.

Wherever needed, tables comparing the methodologies of the three utilities are presented to summarize the text discussion. Each table covers the current practices at each utility and attempts to be comprehensive. Any information on the historical or future operations of these programs is presented only in the text.

Some descriptive statistics on each company's size in 1978 are presented in Table 9. Of the three utilities, SoCal is by far the largest, followed by CP&L and then LILCO. Both SoCal and LILCO are summer peaking companies while CP&L is dual-peaking (dual-peaking means the peak season alternates from summer to winter).

2.2 DATA REQUIREMENTS AND PRIORITIES

The load research programs at CP&L and SoCal were initiated by their rate departments and the LILCO effort began in the systems engineering department. As noted in Sec. 1.2 (this volume), in addition to rate design, there are several traditional and new uses of load research. Table 10 summarizes each company's research objectives. Of the traditional objectives, all three utilities use load research for cost-of-service allocation studies, rate design, load forecasting, and system design. SoCal uses load research in a conservation program to identify where demand reduction would be most effective.

Table 9 Description of Companies included in Load Research Survey, 1978

Characteristic	CP&L	LILCO	SoCal
Number of customers (10^3)[a,b]	702	883	2,950
Residential[c]	595	798	2,617
Commercial[c]	102	45	325
Industrial[c]	3	36	2
Annual electricity output (GWh)	29,702	13,719	63,877
Annual electricity sales (GWh)[b]	27,994[a]	12,438[d]	57,027[a]
Residential[c]	7,207	5,559	15,369
Commercial[c]	4,502	673	16,478
Industrial[c]	9,013	5,586	18,976
Peak demand (MW)[a]	5,605	2,997	11,997
System capability (MW)	7,796	3,968	14,805
Peak season	dual	summer	summer
Annual load factor	0.60	0.52	0.61

[a]Moody's Public Utility Manual, Moody's Investor Service, pp. 327, 330, 1075, 1079, 1776, 1779 (1978).

[b]Sum of residential, commercial, and industrial does not equal total listed because of miscellaneous customers (municipal, railroad, rural, etc.) who do not fit in these three categories but who are accounted for in total.

[c]Uniform Statistical Report, Securities and Exchange Commission, Schedule XIV, lines 2 and 3 (1978).

[d]R.E. Ashburn, LILCO, personal communication (July 1980).

All three utilities also use load research as a basis for evaluating time-of-use pricing and load management. Specifically, CP&L uses load research data to design time-of-use rates. CP&L recently completed a time-of-use pricing experiment where customer participation was mandatory. Both LILCO and SoCal are now conducting time-of-use pricing studies. The objective of these experiments is to measure customer responses to specific time-of-use price schedules. Both CP&L and SoCal have carried out load management experiments on residential electric water heaters and air conditioners; LILCO is conducting a thermal energy storage project.

In the course of a load research experiment, data are collected relating to various aspects of customer usage. The detail of the data collected by the three utilities and the interval over which they are recorded are presented in Table 11. All three utilities collect data on electricity usage; two companies also gather weather data. SoCal collects weather data at 15-min intervals, while LILCO, for certain load management studies, records weather data at 60-min intervals. All three utilities collect electricity data by kilowatt over 15-min recording intervals. Kilowatt-hour data can be computed

Table 10 Uses of Load Research

Use	CP&L	LILCO	SoCal
Year research began	1969	1964	1970
Department initiating research	Rates and Service Practices	Systems Engineering	Revenue Requirements
Traditional uses			
Cost-of-service allocation	yes	yes	yes
Rate design	yes	yes	yes
Marketing	no	no	yes[a]
Load forecasting	yes	yes	yes
System design	yes	yes	yes
New Uses			
Time-of-use pricing	yes	yes	yes
Load management	yes	yes	yes

[a]Conservation and load management program evaluation.

Table 11 Data Requirements and Priorities

Data Characteristics	CP&L	LILCO	SoCal
Electricity data			
Kilowatt recording interval	15 min	15 min	15 min[a]
Unit of observation	kW, kWh	kW, kWh	kW, kWh
Weather data			
Recorded	no	yes[b]	yes
Recording interval	not applicable	60 min	15 min
Stratification framework	subjective[c]	statistical	subjective[c]
Stratification variable	kW or kWh	kW or kWh	kW and/or kWh
Survey characteristics			
Duration	one year	one year	continuous
Reporting interval	one year	one year	one year
Frequency	continuous[d]	continuous	continuous
Sample rotation[e]	downtime	cycle	tune-up
Data borrowed from other companies	no	no	no

[a]Uses 5-min interval for air conditioning load studies.

[b]For certain load management studies.

[c]Uses historic rate schedule breakpoints to define strata.

[d]Except for downtime.

[e]See Sec. 1.2.4 (this volume) for explanation.

by summing the appropriate kilowatt data over the desired time period. SoCal obtains data on reactive current for large power groups but does not use this information for load studies.

As noted in Sec. 1.3.2 (this volume), there are two ways to stratify a sample: subjective and statistical. Table 11 summarizes the stratification framework and variable for each company. Both CP&L and SoCal use a subjective framework. The stratification variable is the variable (i.e., kilowatt-hours or kilowatts) used to determine breakpoints in the respective customer class (historic or current) rate schedules. The strata are discussed in greater detail in Sec. 2.3 of this chapter. LILCO uses a statistical framework for stratification and kilowatts as the stratification variable wherever possible. Where kilowatt data are unavailable, kilowatt-hours are used.

Data are collected for each sample group over the course of the survey. The duration and frequency of the surveys vary across utilities. CP&L's surveys generally last one year and are continual except for the time required to change meters from the old sample to the new one. These changes are always made during nonheating or cooling periods to insure that class loads are recorded during system and class peak periods. Historically, CP&L's surveys have lasted for only the three summer and three winter months rather than the current 12-month period. The duration of LILCO's surveys is one year; the company surveys continually. Finally, SoCal's surveys are ongoing and continual.

Since SoCal has ongoing surveys, only tune-up meters (see Sec. 1.2.4, this volume) are relocated, with most meters remaining on the original sample customers. LILCO uses a cycling approach to change samples. That is, meters from old sample customers are installed on new sample customers. This is done by switching a portion of the meters from first-sample customers to second-sample customers by the end of the first sample period. Then the company spends the next few months relocating the remaining meters and getting the second sample to full size. CP&L waits until the end of a survey period, which is normally at the end of the summer or winter peak season, to remove meters and then installs these meters on the new sample in time to record the next summer or winter peak period. This technique requires "downtime" for the transfer. Section 1.2.4 (this volume) describes these three techniques in more detail and reviews their strengths and weaknesses.

In addition to the types of data to be collected, the class to be surveyed and the sampling method to be used must also be determined prior to starting a load survey. The choices depend on the objectives of the load research program. Table 12 summarizes the major customer classes and subclasses sampled by each company. In general, all three companies survey their residential, commercial, and industrial classes at some level of aggregation. Both CP&L and LILCO disaggregate their residential class to some degree while SoCal does not. CP&L is currently undertaking load studies for a single residential rate class. Both CP&L and SoCal disaggregate their industrial class to some degree while LILCO does not. It should be noted that industrial load research data are often available from billing meter tapes. (The time-of-use samples do not necessarily follow similar breakdowns.)

Table 12 Summary of Customer Classes and Subclasses Sampled

Rate Class	CP&L	LILCO	SoCal
Residential	-	-	yes
General	yes	yes	-
Electric water heat	yes	-	-
Electric space heat	yes	yes	-
Commercial[a]	yes	yes	yes
Industrial[b]	yes	yes	-
1,000-5,000 kW	-	-	yes
Over 5,000 kW	-	-	yes

[a]CP&L classes: small general service and general service.
LILCO class: general service, small.
SoCal class: lighting and small power.

[b]CP&L classes: general service and large general service.
LILCO class: general service, large.
SoCal classes: large power and industrial time-of-use.

A number of decisions must be made before sampling from a given population. The decisions made by the three utilities can be organized into three groups: general aspects of sample design, stratified random sample designs, and selection of the strata used in the stratified random samples.

The initial question to be addressed when conducting a load survey is whether to meter customers in groups or individually. All three utilities use only individual metering, because their populations are sufficiently heterogeneous to make group metering infeasible.

All three utilities use the stratified random sampling method, which is the most commonly used method in load research (as noted in Sec. 1.3, this volume). SoCal also uses systematic sampling for air conditioning load studies. To determine the sample size, the desired reliability and confidence levels of the stratification variable must be determined. For most customer classes, all three utilities use a 95% confidence level. Both CP&L and SoCal use a 10% reliability level, while LILCO uses a 5% reliability level for most classes. LILCO and SoCal use a computer program to generate random numbers, while CP&L uses a random number calculator program. Random number computer programs are available as software packages.

Table 13 sets out the procedures used by the three utilities to construct a stratified random sample. Setting up a stratified random sample involves four decisions, in addition to the choice of the stratifying variable: location of strata breakpoints, number of strata, strata allocation technique, and sample size and estimate of sample variance.

Table 13 Stratified Random Sample Designs

Characteristics	CP&L	LILCO	SoCal
Stratification framework	subjective	statistical	subjective
Stratification variable	kW, kWh	kW, kWh	kW, kWh
Determination of strata breakpoints	rate schedule breakpoints[a]	Dalenius and Hodges	rate schedule breakpoints[a]
Determination of number of strata	rate schedule blocks	coefficient of variation	rate schedule blocks
Allocation of meters to strata	Neyman	Neyman	Neyman
Determination of sample size	coefficient of variance and confidence level of kilowatt demand	coefficient of variance and confidence level of stratification variable	coefficient of variance and confidence level of stratification variable
Variance estimation	obtained from previous samples	obtained from population distribution	obtained from previous samples
Tests for sample randomness	compare sample and population	chi-square test[b]	chi-square test[b]

[a]Historical, not current, rates are the basis for current load research studies.

[b]See Applied Statistics in Load Research, Association of Edison Illuminating Companies, New York City, Vol. 2, pp. 169-207 (1965).

For CP&L and SoCal, the number of strata and the location of strata breakpoints are determined by the breakpoints in the relevant customer class rate schedules. Therefore, no statistical procedures are required for these decisions. However, CP&L has confirmed the location of its breakpoints using the Dalenius and Hodges procedure (see Sec. 1.3.5 and Appendix B, Sec. B.7, both in this volume, for a discussion of this procedure). LILCO, on the other hand, uses statistical procedures to design its stratified random sample. The company uses the Dalenius and Hodges procedure to determine strata breakpoints and uses the coefficient of variance to determine the number of strata.

The next decision to be made concerns the allocation of meters to each sample stratum. All three utilities use the Neyman optimal strata allocation procedure for stratified random sampling. If the Neyman procedure allocates less than 30 meters to a strata, LILCO raises the number of meters to 30 (see Sec. 1.3.5 and Appendix B, Sec. B.6, both in this volume, for a discussion of the Neyman procedure).

As noted above, the coefficient of variance and the confidence level are used to determine total sample size. An estimate of the sample variance also is required prior to the actual sample selection. Since the sample variance cannot be known prior to sample selection, a rough estimate must be obtained from other data. Initially, CP&L obtained kilowatt demand variance estimates from Duke Power Company's load research data, since this utility's service area closely resembled its own. Currently, estimates are obtained from CP&L's previous samples. LILCO estimates sample variance from the population distribution, i.e., the population variance is used as an estimate of the sample variance. Originally, SoCal obtained sample variance estimates from population data. Currently, like CP&L, the company bases its estimates on its own previous samples. See Sec. 1.3.4 (this volume) for a discussion of estimating sample variance.

Finally, once the sample is selected, there are various methods of testing whether sample characteristics adequately replicate the population characteristics, i.e., whether the sample is random. CP&L compares sample characteristics such as mean kilowatt-hours and mean billing kilowatts to population mean values while both LILCO and SoCal perform a chi-square test.*

Tables 14, 15, and 16 display the strata breakpoints used by each company for sampling and the number of meters in each stratum. For CP&L and SoCal, strata breakpoints for most classes are the breakpoints of historical rate schedules for that class. These breakpoints normally occur where there is a change in the homogeneity of the customer usage, a change caused by different appliance mixes. The one exception is SoCal's large power and industrial time-of-use classes, which are stratified on the basis of current rates.

For CP&L, the strata are defined in terms of monthly electricity use (kilowatt-hours) for the residential rate classes and in terms of electricity demand (kilowatts) for the general service rate classes. The sampling is done on the basis of monthly consumption or demand (as applicable) during the month of system peak, which is a summer month. CP&L has revised and added some strata breakpoints in some of its general service rate classes to improve the homogeneity of the groups and thereby reduce the variance of the strata. This has allowed the company to reduce the overall sample size and yet maintain the same level of precision and reliability. Load research is now being conducted using the new strata. However, no results are yet available.

LILCO's strata breakpoints are determined statistically. The kilowatt is the prime stratification unit. When kilowatts are unavailable, kilowatt-hours are used.

For SoCal, the strata are expressed in terms of annual electricity use (kilowatt-hours) for the nondemand-metered rate classes, in terms of both annual use and demand (in kilowatts) for the lighting and small power metered class, and by demand for the large power and industrial time-of-use class. The sampling is done on the basis of either use or demand or both depending on

*For a discussion of the chi-square test, see Ref. 7.

Table 14 Strata Used by Carolina Power and Light Company (by rate class)

Rate Class/Strata	No. Meters in Sample Strata
Residential (kWh/month)	
R2 - All electric: summer[a]	
0-700	16
701-1400	26
1401-2500	24
over 2500	14
R2 - All electric: winter	
0-2500	not applicable
2501-4000	not applicable
4001-6000	not applicable
over 6000	not applicable
R3 - Electric water heat	
0-350	7
351-750	22
751-1400	20
over 1400	26
R4 - General	
0-150	5
151-350	21
351-750	18
over 750	31
Commerical and industrial (kW)	
Small general service	
0-5.5	40
5.6-51	125
52-1000	40
over 1000	14[b]
General service	
0-100	10
101-500	40
501-1000	30
1001-5000	16
over 5000	4[b]
Large general service	
0-2000	30
2001-5000	50
over 5000	50[b]

[a]Stratified on basis of monthly consumption during month of system peak. System peaks in the summer.

[b]100% sample.

Table 15 Strata Used by Long Island Lighting Company (by rate class)

Rate Class/Strata	No. Meters in Sample Strata
Residential (kWh/yr)	
General and water heat	
0-3,200	47
3,201-5,600	30
5,601-8,000	30
8,001-11,200	30
11,201-18,000	30
18,001-98,600	34
Space heating	
0-7,400	9
7,401-12,700	9
12,701-18,200	9
18,201-25,300	9
25,301-37,400	9
37,401-98,800	15
Commercial and industrial	
Small - no demand charge (kWh/yr)	
0-2,300	10
2,301-4,800	8
4,801-7,900	9
7,901-11,900	9
11,901-18,100	9
18,101-94,100	16
Space heating	40
Large: maximum demand is 0-50 kW	111
Large: maximum demand is 51-750 kW (excluding schools)	
51-130	59
131-310	45
311-750	45
Large: schools, maximum demand is 51-750 kW	
51-100	7
101-160	6
161-270	7
271-430	7
431-750	9

Table 16 Strata Used by Southern California Edison Company (by rate class)

Rate Class/Strata		No. Meters in Sample Strata
Domestic (kWh/yr)		
0-2,160		27
2,161-3,360		31
3,361-4,920		42
4,921-8,880		45
8,881-30,000		61
Commercial and industrial		
Lighting and small power (kWh/yr)		
General service - nondemand metered		
0-3,000		51
3,001-9,600		35
9,601-36,000		33
General service - demand metered		
0-54,000	1-30 kW	32
over 54,000	1-30 kW	17
0-54,000	over 30 kW	32
over 54,000	over 30 kW	52
Large power (kW)		
200-499		35
500-1,000		1200
Industrial time-of-use (kW)		
1,000-5,000		740[a]
over 5,000		120[a]

[a]100% sample.

the variables used to determine rates. The annual breakpoints for kilowatt-hours are obtained by multiplying the monthly rate schedule's breakpoints by 12.

2.4 CUSTOMER PARTICIPATION AND EXCLUSION

Table 17 summarizes each company's reasons for excluding customers from survey samples. While none of the utilities systematically excludes any customers from its samples, there may be instances when customers are excluded because sampling them presents access difficulties, such as unsafe conditions for meter reading. Although public utilities have the legal right to install a meter in any dwelling unit, most firms first seek customer approval. Both CP&L and SoCal exclude customers who do not wish to be metered for the sample.

Table 17 Customer Participation and Exclusion

Characteristic	CP&L	LILCO	SoCal
Back-up for primary sample	alternate samples	alternate samples	no
Reasons for company exclusion of customers	multiple dwelling units, new customer,[a] or impossible to meter	customer presents unsafe conditions	customer presents access difficulties
Incentives to included customers	no	no	no
Voluntary participation	yes	no	yes[b]
Demographic data			
Questionnaire used	yes[c]	yes	yes
Classes questioned	all	residential	residential
Type of data	see Appendix C, this volume	appliance, type of house, household size	appliance, type of house, household size

[a]Less than six months.

[b]Excluding time-of-use experiments.

[c]Company personnel conduct interviews.

On the other hand, LILCO will meter at the pole, without customer approval, any customer who objects to being included in the sample. CP&L also has other reasons for excluding customers from a sample; new customers with less than six months' billing history and multiple dwelling units are excluded. Both CP&L and LILCO have alternate samples as back-ups for the primary samples. None of the utilities offers incentives to sample customers to encourage participation.

At the time customer approval is obtained, SoCal asks residential sample customers to complete a questionnaire concerning demographic, appliance, and building structure characteristics. SoCal expects to expand its questionnaire considerably in the future. LILCO conducts appliance surveys well after the load research survey has begun. CP&L personnel conduct interviews and complete questionnaires for all sample customers (a copy of CP&L's questionnaire can be found in Appendix C, this volume).

2.5 RECORDING EQUIPMENT SELECTION AND INSTALLATION

Three types of equipment are required for load research: recorders, pulse initiators, and meters. Table 18 summarizes the characteristics of each company's load research equipment.

Table 18 Recording Equipment and Installation

	CP&L	LILCO	SoCal
Type of recorder	magnetic tape[a]	magnetic tape	magnetic tape[b]
Magnetic tape recorder			
No. of channels	2, 4	2, 4	2, 4
Medium	cartridge and cassette	cartridge	cartridge
Manufacturer	Westinghouse cartridge, Duncan and Sangamo cassettes	Westinghouse, General Electric	Westinghouse, General Electric, Duncan, and Sangamo
Manpower			
Install recorder	meter testmen	meter testmen	meter testmen
Change recorder tape	serviceman or meter reader	meter testmen	meter testmen
Tape length	35 days	30 days	30 days
Pulse initiator	prefers mechanical, uses both	prefers electronic, uses both	prefers electronic, uses both
Battery carry-over	90% of meters	some meters	some meters
Location of recorder	outside dwellings	outside or inside, depending on type of customer	outside or inside, depending on type of customer

[a]Has examined Robinton and Process Systems solid state equipment.

[b]Experimenting with Robinton solid state system.

All three utilities now use magnetic tape recorders, although they are investigating the feasibility of using solid state equipment for future research. LILCO and SoCal use only cartridge tape recorders but CP&L uses both cartridge and cassette tape recorders. Depending on the type of data to be collected, the companies use either two- or four-channel recorders. The cartridges and cassettes are installed by meter testing personnel, and the tapes are changed approximately every 30 days. CP&L employs service personnel or meter readers to perform the latter function.

All three companies use both mechanical and electronic pulse initiators. Of the three companies, only CP&L prefers mechanical initiators, which it has found to be more reliable and require less maintenance than the electronic ones. The other two utilities prefer electronic initiators, which they have found to be more reliable than mechanical ones. Both CP&L and SoCal mainly use recorders with battery carry-over in case of power outages. LILCO uses recorders with battery carry-over only for certain studies.

CP&L installs recorders outside the dwelling unit. Both LILCO and SoCal install recorders either inside or outside the building depending on the type of customer.

The costs of various types of load research equipment are estimated in Sec. 1.5.1 (this volume).

2.6 ERROR DETECTION AND TAPE TRANSLATION

The three utilities record all load research data on magnetic recording tapes. These tapes, in order to be used in any analysis, must be translated onto computer tapes compatible with in-house computers. Each utility has its own translator that performs this function. All three utilities use a WLT-40 translator manufactured by Westinghouse. Translation is carried out by the Load Research Unit of the Rates and Services Practices Department at CP&L and by the Metering Departments at LILCO and SoCal. In the course of translating the tapes, each company has a set of checking procedures to insure that the final computer tapes meet certain criteria on the allowed level of tape errors. As discussed in Sec. 1.5.3 (this volume), a number of errors can occur due to human mistakes, mechanical or electronic failure, tape wear, or power outages.

2.7 DATA STORAGE

All three utilities have two types of in-house computers: one or more minicomputers and one or more main computers. At both CP&L and SoCal, data are stored on the minicomputer on disk, and at all three utilities, data are stored on tape and can be loaded onto the main computer. Both CP&L and LILCO use their minicomputers solely for current data translations, while SoCal stores one month of load data on its minicomputer and maintains a tape library at the minicomputer with one full year of data. CP&L performs all possible edits and data corrections on the minicomputer before transferring the data to the main computer. As can be seen from Table 19, historical data have been stored on the main computers beginning in 1970 for CP&L, 1965 for LILCO, and 1972 for SoCal.

Load data are recorded, edited, and stored in 15-min intervals at all three companies. For some studies, LILCO edits and stores data in 60-min intervals. The storage format is sequential at LILCO and incomplete sequential at CP&L and SoCal (see Sec. 1.7, this volume, for a discussion of these two types of formats). Tapes can be either labeled or unlabeled, but all three utilities label their tapes according to the IBM standard. Kilowatt data can be stored by pulse or demand. CP&L and SoCal store by pulse count and carry a pulse multiplier, while LILCO stores by demand. Finally, data other than kilowatt data may be stored. Both LILCO and SoCal store weather data, and SoCal also stores demographic data for its time-of-use experiments.

Table 19 Data Storage and Display

Characteristic	CP&L	LILCO	SoCal
Minicomputer	Hewlett-Packard MX21	Hewlett-Packard MX21	Hewlett-Packard MX21
Main computer	IBM 3031 and 3032	IBM 370	IBM 370
Earliest year of test data	1970	1965	1972
Kilowatt recorded interval length	15 min	15 min	15 min
Kilowatt edited and stored interval length	15 min	15 min and 60 min[a]	15 min
Storage format	incomplete sequential (monthly)	sequential	incomplete sequential (monthly)
Pulse or demand storage	pulse	demand	pulse
Tapes labeled	yes	yes	yes
Other stored data			
Demographic	no	no	yes
Weather	no	no	yes
Extrapolation basis	customers	customers	customers
Restratification	fix break-points; re-locate cus-tomers	Fix break-points; does not relocate customers	fix break-points; relo-cate custom-ers

[a]Depends on type of study.

2.8 DATA DISPLAY AND ANALYSIS

The types of load research data that are displayed and the analyses done with the data vary depending on the objectives of a load research study. Consequently, this section does not attempt to exhaustively list the three companies' procedures for data display and analysis. Rather, some examples are provided for each utility.

2.8.1 Carolina Power and Light Company

The types of load research data collected by CP&L and the analyses of these data can be summarized as follows.

Individual Sample Customer Data

- Each sample customer identified by an 11-digit identity number and a revenue account number
- Total kilowatt usage for the test period
- The 60-min kilowatt demand at the time of the system peak
- The 60-min maximum kilowatt demand for the period with date and time of occurrence
- Load factor for the monthly period, expressed as: load factor = (monthly kilowatt-hours)/(kilowatt demand x hours in month)
- The 60-min kilowatt demand at the times of the stratum, rate, and group maximum diversified demands

Stratum Data

- Average kilowatt-hour usage per customer for the stratum
- The 60-min average kilowatt demand per customer at the time of the system peak with:
  - summation of the demands
  - number of customers contributing
  - monthly load factor
- The 60-min average maximum kilowatt demand per customer with:
  - summation of the demands
  - number of customers
  - monthly load factor
- The 60-min average maximum diversified kilowatt demand per customer with:
  - summation of the demands
  - number of customers
  - date and time of occurrence
  - monthly load factor
- The diversity factor expressed as:

$$\text{Diversity factor} = \frac{\text{maximum kilowatt demand}}{\text{maximum diversified kilowatt demand}}$$

- The coincidence factor expressed as:

$$\text{Coincidence factor} = \frac{\text{maximum diversified kilowatt demand}}{\text{maximum kilowatt demand}}$$

Rate Class Data

- The weighted average kilowatt-hour usage per customer for the rate with:

- each stratum's weight expressed as a percentage of total population
- each stratum's average kilowatt-hour usage per customer used in calculation
- each stratum's contribution to the rate average kilowatt-hour usage per customer

- The weighted 60-min average kilowatt demand per customer at the time of the system peak with:
  - total number of customers contributing
  - monthly load factor

- The weighted 60-min average maximum kilowatt demand per customer with:
  - number of customers
  - monthly load factor

- The weighted 60-min average maximum diversified kilowatt demand per customer with:
  - each stratum's weight expressed as a percentage of total population
  - each stratum's average maximum diversified demand per customer used in the calculation
  - each stratum's contribution to the average kilowatt demand for the rate
  - date and time of occurrence
  - monthly load factor
  - diversity factor
  - coincidence factor

<u>Customer Group Data</u>

- The weighted average kilowatt usage per customer for the class with:
  - each rate's weight expressed as a percentage of total population
  - each rate's average kilowatt-hour usage used in the calculation
  - each rate's contribution to the class average kilowatt-hour usage

- The weighted 60-min average kilowatt demand at the time of system peak with:
  - number of customers contributing
  - monthly load factor

- The weighted 60-min maximum diversified kilowatt demand per customer with:
  - each rate's weight expressed as a percentage of population
  - each rate's kilowatt demand used in the calculation
  - date and time of occurrence
  - number of customers
  - monthly load factor

- diversity factor
- coincidence factor

2.8.2 Long Island Lighting Company and Southern California Edison Company

A number of basic analyses of load research data are used by LILCO and SoCal. Some of these analyses involve the computer-based load research system (on their main computer), i.e., software packages that contain statistical and analytical algorithms applicable to load research data, while other analyses are simply plots or graphs. The types of data and display that are usually employed can be summarized as follows.

Both companies use a computer run that details information on kilowatt-hour use, peak kilowatts, and time of peak over different time periods. Beginning with the most disaggregate time period and moving toward the most aggregate, this computer run includes:

- Kilowatt data for individual customers or groups of customers for every 15-, 30-, or 60-min interval, for a specified day of the year. Total kilowatt-hours and peak kilowatts are included at the end of each day with the number of customers in each group.
- Customer group kilowatt-hour use, peak kilowatts, and time of peak for each day of a specified month. Total monthly kilowatt-hours, monthly peak kilowatts, and day of peak are included at the bottom of this print-out page.
- Customer group kilowatt-hour use, peak kilowatts, and date and time of peak for each of the 12 months individually. Total annual kilowatt-hours, annual peak kilowatts, and date of first occurrence of peak kilowatts appear at the bottom of this print-out page.
- Total kilowatts that occurred on all Mondays, all Tuesdays, etc. over 15-, 30-, or 60-min intervals for the entire system for the year. Total kilowatt-hours for each day of the week appear at the bottom of this print-out page. Daily averages of these data may also be displayed.
- For the time-of-use survey, the hours included in specific rating periods, i.e., peak, midpeak, and off-peak periods.
- Peak kilowatts and kilowatt-hours for each rating period for each customer group.
- Diversity and coincidence factors and noncoincident demands.

The companies also produce graphs of individual and customer group hourly kilowatts for an average day (a comparison of several years' data is sometimes made) and load profiles of various domestic customer groups. Statistical analyses, including correlation and regression, are sometimes made using the various sets of data.

Some special studies conducted at SoCal include a peak responsibility study comparing individual group demands to system demands, an annual load study for all customer groups, a time-of-use report on time-of-use customer activity, and analyses of load impacts for various load management projects.

2.9 ORGANIZATION AND MANAGEMENT

Figure 9 displays the organization of CP&L's Load Research Unit and its relation to other groups in the company. The load research effort involves sections or units from three corporate groups, each having a distinct function. Metering is performed in the System Meter Laboratory. Data processing is under the supervision of the Information Management Department. The basic function of data processing, as part of the load research effort, is to store load data. The Load Research Unit is directed by the Rate Research Section. Tapes are translated and data adjusted by members of the Load Research Unit. A Load Research Project Team, composed of representatives from all departments involved in implementing and conducting the load research effort, meets as necessary to provide cohesive direction and coordination.

At LILCO, two major groups -- the Meter and Test Department and the Load Research and Load Management Division of the Economic Research Department -- are actively involved in the day-to-day load research effort (see Figure 10). Although these groups interact with other departments of the company, communication between themselves is an integral part of the load research program. The manager of the Economic Research Department coordinates all load research activities. The responsibilities of the Load Research and Load Management team include: establishing data requirements and priorities, designing samples, analyzing load data, and preparing reports. The Meter and Test Department performs metering and translates tapes.

Four departments are involved in the load research effort a SoCal: System Development, Power Supply, Data Processing, and Revenue Requirements. Each is responsible for certain load research activities (see Figure 11).

Within the System Development Department is the System Planning Division. A Load Survey System Sponsor is selected from this division to coordinate the interaction of all four departments involved and to insure the integrity of the Load Survey System for other user departments. The Data Acquisition group (Power Supply Department) is responsible for metering and tape translation. Translated tapes are then sent to the Data Processing Department, where the main computer is located. The load research unit of the Data Processing Department is responsible for the storage of load data. The load research unit of the Revenue Requirements Department is responsible for all other aspects of load research, including data requirements and priorities, sample design, and conducting the survey and data analysis. This unit prepares the software needed for data analysis beyond certain routine retrieval programs provided by the Data Processing Department.

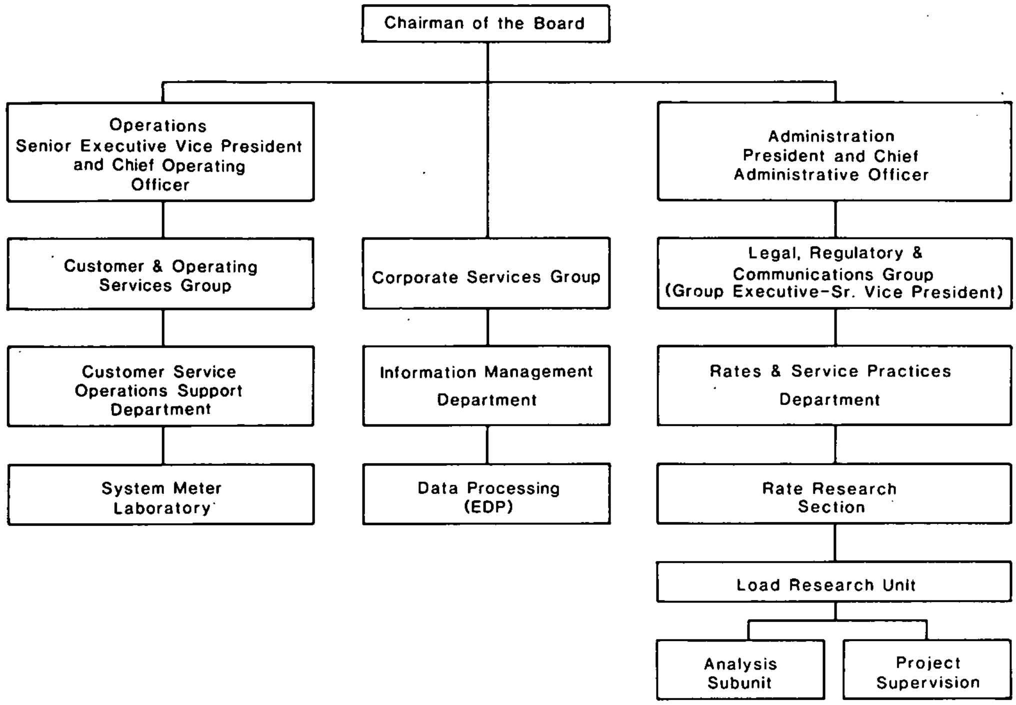

Fig. 9 Carolina Power and Light Company Organization

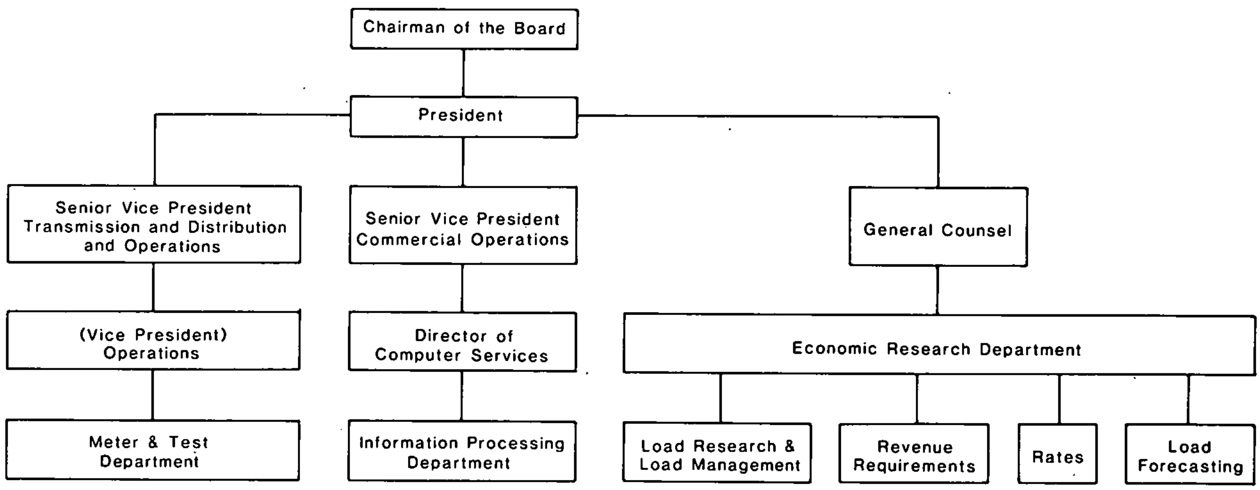

Fig. 10 Long Island Lighting Company Organization

The personnel involved in setting up and supervising the various aspects of load research usually have degrees in engineering, mathematics, or computer sciences, with some knowledge of economics and statistics. While surveys may be designed and conducted by in-house personnel, outside consultants are usually employed to assist in the preparation of the sample design.

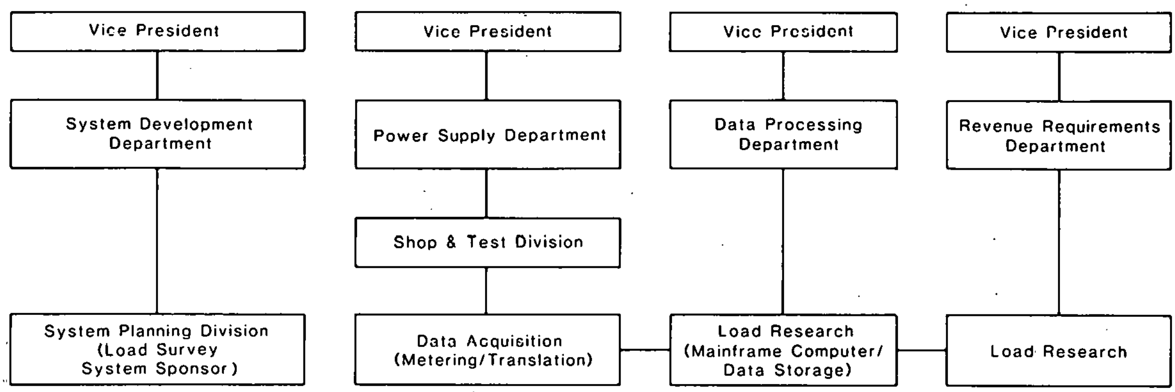

Fig. 11 Southern California Edison Company Organization

3 SUGGESTIONS AND CONCLUDING REMARKS

This volume has described several procedures and frameworks for implementing load research. It also has attempted, where necessary, to caution the reader against too strict an adherence to the suggested guidelines. This chapter will more comprehensively discuss these caveats, several of which have appeared elsewhere in the text.

The first step in implementing a load research survey is to define the objectives and their attendant data requirements. Inevitably, several later decisions that a researcher will face depend on a clear resolution of the purposes of the survey. Therefore, it is necessary that objectives be defined and adhered to. Researchers must be cautious not to define too many objectives lest they fail to achieve any at all.

Upon designing a timetable, the researcher must plan ahead and allow as much flexibility as possible. Well in advance of the time that a procedure is actually to be implemented, personnel should be trained, equipment purchased, and plans made for its use. Software and equipment development especially cannot be postponed until the last moment. Since significant lead time should be allowed, substantial flexibility -- especially in computer and translator software purchases -- should be incorporated since the research may evolve in an unexpected manner or new priorities may arise.

Statistical procedures can be useful in designing an efficient load research sample. Since such procedures can enhance statistical reliability and confidence, they can enable the necessary sample size to be reduced. A sampling statistician should be employed to design the sample. However, since load research data can present special problems, an experienced load researcher who is cognizant of the issues should work with the sampling statistician. Additionally, the resulting statistics from any research effort should correspond with "common sense" magnitudes.

Costs and budget constraints should be well-specified and always considered. Cost-cutting is necessary when financial resources are limited. However, certain equipment and methods are probably worth the additional expense once the long-run savings are considered. Therefore, a careful assessment of research priorities and costs is especially necessary if the budget is limited.

Load research equipment is constantly changing. Contact with several manufacturers is essential, since each may offer a particular benefit worthy of consideration. Solid state equipment is falling in price, enables remote data collection, circumvents the expense of an automatic translator, and is adaptable to load control and data display. The advent of miniaturized meters is also possible. The buyer must remember that the market presents tremendous opportunities for equipment improvement and must therefore astutely leverage the firm's equipment purchases over time to exploit fully this fortunate situation.

The most relevant load research will result when the load research department interacts effectively with other departments in the utility. To this end, departmental interfacing among load researchers and rate designers, system designers, load forecasters, and marketers is necessary. Since a substantial amount of money is to be spent and can be wasted in metering, data translation, and data storage, the load research department also must interact effectively with groups responsible for these activities. Central administration is worth considering.

Wherever costs permit, novice load researchers should seek the advice of experts: other utility research groups, sampling statisticians, professional survey groups, consultants, academicians. Advice is most effective when obtained early in the project. When costs are a problem, the research team must identify its weakest areas and incorporate the most substantial professional advice there. Advice must be tempered with a careful assessment of the company's needs and concerns, and no aspect of any load research project should be abandoned totally to a group of hired specialists.

If possible, novice load researchers should initially undertake a small project to ascertain best the pitfalls that will be encountered. This education can prove quite worthwhile once a larger survey is pursued.

The sample design must allow for recording errors, machine malfunctions, and customer attrition. By contacting other experienced companies, a research team may assess the necessary "reserve margin" and appropriately oversample the population. Because this margin can vary with customer and equipment type, careful investigation of these error parameters can prove worthwhile.

If possible, the determinants of customer electricity demand should be analyzed. As these determinants change in the future, load magnitude can then be adjusted and additional survey expenses saved. A reliable appliance saturation survey could be quite useful.

Considerable time and expense can be saved if load research data are rigorously related to underlying factors. These factors then may serve as the basis for "best estimates" in the future, thereby eliminating the need for repeated surveys. End-use and customer load shapes can be related to sociodemographic variables, household structural characteristics, appliance saturations and prices, and incomes. Future load research might then concentrate more on improved statistical analysis. Future load research can serve as the basis for evaluating alternative load management strategies, price elasticities, rate reform, likely usage changes, and possible load shape or load factor changes.

When a utility participates in a joint research venture with or borrows data from another utility, load research results must be adjusted for its service area unless the populations in the two service areas are identical. These results may be corrected for differences in appliance stock, economic factors, etc. Since "best estimates" may be filed legally to meet some PURPA requirements, it seems that joint ventures and data borrowing with appropriate adjustments may be proper and useful load research procedures.

While statistical analysis and adjustments may mitigate the need for periodic resurveying, they will enhance the need for more-detailed and more-precise data collection. Techniques and adjustments must be respecified once more-accurate data become available. More-detailed customer surveying becomes essential. Additionally, load researchers might become more familiar with various federal, state, and local government data sources.

Since much of government and utility conservation and load management policy appears to concern individual end uses of electricity, future research should more extensively investigate separate, variable end uses. In this way, one may evaluate, for example, the potential for load control of water heaters for reducing the system peak. While much end-use research has been completed with residential customers, end uses in the industrial and commercial sectors could be studied far more extensively.

Future load research also must deal more explicitly with time-of-day pricing, actual load management techniques, and alternative technologies. Load researchers in these areas must realize the different nature of these problems and deal with each accordingly. Appropriate specialists should be hired to design samples and conduct surveys when new aspects of load research require attention.

Of special concern is the effect of weather discomfort upon system, customer, or appliance loads. Up to this point, researchers have appeared to explain the air conditioning load as a linear function of cooling degree-days or the temperature-humidity index. There is no reason to assume this effect is indeed linear; the first few degrees of discomfort might cause relatively little usage response while the next few may bring sizable increases in customer demand. Additionally, wind speed, cloud cover, humidity, and perhaps rainfall all contribute to perceived weather discomfort. Furthermore, thermal buildup from previous hours or days may exert a substantial effect on load; many utilities attribute the occurrence of a summer peak to a few days of heat buildup. Finally, more-precise knowledge of the nature of weather discomfort would be useful in formulating peak load pricing, efficiency, and insulation policies.

Standardization of procedures and techniques and centralized reporting of results deserve special attention. If load research studies from several utilities are assimilated (as in the Reznek and Gilbert Associates studies listed in the bibliography of this volume), information can be made available to any interested party for whatever purpose. If procedures are standardized, more-economic use of another utility's research is possible. Editing procedures should be standardized, and software and reporting formats can be standardized to permit the same basic analysis across different surveys. Data can be more readily transferred once data tapes are standardized in a basic format. Finally, instruction tapes on various important topics should be updated and standardized.

It is not clear what role (e.g., referee, enforcer) state regulatory commissions will play between utilities and FERC. However, it is anticipated that this role will be important, as it has been for rate setting decisions. Therefore, it may be desirable for electric utilities to seek continuing advice from their state regulatory commissions regarding compliance with PURPA standards. Utilities can request exemptions from FERC requirements if they are unable to provide certain types of load data by the required filing date. Such exemptions are granted on a case-by-case basis by FERC or a state regulatory commission.

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GLOSSARY OF LOAD RESEARCH TERMS*

actual demand--see demand.

all-electric home--a home in which electricity is the principal source of energy for space heating and cooling, water heating, cooking, lighting, and other power requirements.

ampere (EEI)--unit of measurement of electric current. It is the unit current produced in a circuit by one volt acting through a resistance of one ohm. It is analogous to cubic feet of water per second.

annual--pertaining to any 12 consecutive calendar months.

appliance saturation--ratio of the number of appliances to the total number of customers in the group, expressed as a percentage.

appliance-customer saturation--ratio of the number of customers having a stated appliance to the total number of customers in the group, expressed as a percentage.

automatic meter reading system (handbook)--a system capable of reading a meter (watt-hour, demand, gas, water, etc.), preparing and conditioning the data, and transmitting (via radio, telephone line, power line carrier, direct cable, or a combination thereof) the accumulated information from the meter location to a central data accumulation device (in most cases a computer). Also called two-way communications system.

average demand--see demand.

average use, kWh--total kilowatt-hour use for a group of customers in a specific period (year, month, day) divided by the average number of customers in the group for the same period. Average monthly use is 1/12 of the annual average use.

average weekday--Monday through Friday, excluding holidays.

billing demand--see demand.

British thermal unit (EEI)--standard unit for measuring quantity of heat energy, such as the heat content of fuel. It is the amount of heat energy required to raise the temperature of one pound of water one degree Fahrenheit.

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*All definitions are AEIC terminology unless otherwise noted. The sources of non-AEIC definitions are noted in parentheses after the term being defined: EEI -- Edison Electric Institute
FERC -- Federal Energy Regulatory Commission
Handbook -- authors of this manual

British thermal units per hour--standard unit of measurement for calculating energy transferred, such as the heat loss or heat gain of a building. It is determined by the difference between indoor and outdoor design temperatures, the roof and wall areas of the structures, and transmission coefficients of the building's roof and walls.

class of service--a classification based on type of customer, service characteristic, type of equipment, or ultimate energy use. More common designations include: rural, residential, commercial, primary distribution, large (or small) light and power, manufacturing, nonmanufacturing, and general service.

clock hour--the 60-min interval ending at any standard hour, usually indicated by the beginning and ending hours (6-7 p.m.) or as hour ended 7 p.m.

coincidence factor--the ratio, in percent, of the maximum demand of a group, class, or system as a whole to the sum of the individual maximum demands of the components of the group, class, or system. As defined, coincidence factor is the reciprocal of the diversity factor and can never be greater than 100%.

coincident--used only to express events occurring over the same time interval, as in "demand coincident with..." Use the expression diversified demand rather than coincident demand.

commercial--a classification covering rates, service, or use for commercial purposes. Unless otherwise defined, commercial establishments are those identified in the Standard Industrial Classification Manual, Office of Management and Budget, 1972, as falling in the following divisions:

A	Major Groups 01-09	agriculture, forestry, fisheries
C	Major Groups 15-17	contract construction
F	Major Groups 50-51	wholesale and retail trade
G	Major Groups 52-59	retail trade
H	Major Groups 60-67	finance, insurance and real estate
I	Major Groups 70-89	services
K	Major Groups 99	nonclassifiable

and such part of Division J, Public Administration, classified as commercial in the two-digit classification.

connected load--the sum of the continuous ratings of the electric power-consuming apparatus connected to a system, part of a system, or customer, usually expressed in kilowatts.

customer--an individual, firm, or organization who purchases electric service at one location under one class of service.

customer load management system (handbook)--a unidirectional-signal system, operated by a utility that (on command from a central station) controls one or more selected customer appliances to improve the system load factor and reduce the peak load.

daily--pertaining to any 24 consecutive hours, usually midnight to midnight.

deferable load (handbook)--a deferred load that, when reenergized, will tend to make up for the time it was down.

degree-day (hour)--see temperature.

demand--the rate at which electric energy is delivered at a given instant or averaged over a designated time interval such as 15, 30, or 60 min. It may be expressed in kilowatts, kilovolt-amperes, or other units for a system, group of customers, or on a per customer basis.

actual demand (FERC)--registered demand.

average demand--kilowatt-hours divided by hours. May be expressed as kilowatt-hours per hour.

billing demand (FERC)--the demand upon which the billing is based as specified in a rate schedule. The billing demand may be greater or less than the actual demand for the billing period.

demand factor--the ratio, in percent, of the maximum demand of a system, part of a system, or individual customer or application to the total connected load of that system, part of system, customer, or application under consideration.

demand interval (EEI)--the period of time during which the energy flow or load is averaged in determining effective demand, such as 15, 30, or 60 min.

diversified demand--the simultaneous demands of a group of appliances or customers taken as a whole. Diversified demands may be determined by direct measurement or by the addition of the load curves of the individual appliances or customers in the group.

group demand--diversified demand.

individual customers' maximum demand--the sum of the maximum demands of two or more customers, usually expressed on a per customer basis. See noncoincident maximum demand.

integrated demand (EEI)--the demand averaged over a specific period, usually determined by an integrating meter or by the integration of a load curve. It is the average of the continuously varying instantaneous demand during a specified interval.

kilovolt-ampere demand--the average kilovolt-ampere demand in a specific time interval. The kilovolt-ampere demand multiplied by power factor is equivalent to the kilowatt demand for the same time interval.

maximum demand--the highest integrated demand of the load under consideration occurring during the specified period of time. The demand may be diversified or noncoincident and may be expressed as a total for a group or on a per customer basis. It may be for a daily, weekly, monthly, or annual period.

noncoincident maximum demand--the maximum demand of any appliance, customer, group, class, or system within a specified period (day, week, month, year) regardless of time of occurrence.

peak demand--maximum demand.

system maximum demand--the maximum demand of an entire system. It is the maximum diversified demand of all classes of customers including losses measured at the point of total system supply.

system peak demand--system maximum demand.

demand factor--see demand.

demand interval--see demand.

design temperature difference--see temperature.

differential register meter (handbook)--a watt-hour meter with two registers so that total energy consumed will be recorded on one set of dials and the energy consumed during a period when the demand is in excess of a predetermined demand level will be recorded on a second set of dials. This is accomplished with a differential gear, one side of which is driven at a speed proportional to a given kilowatt-hour load by a synchronous motor and the other side from the watt-hour meter rotor.

diversified demand--see demand

diversity factor--the ratio of the sum of the individual maximum demands of the components of a group, class, or system to the maximum diversified demand of the group, class, or system as a whole. The diversity factor is the reciprocal of the coincidence factor and as defined can never be less than unity.

double-rate, dual-rate, or two-rate watt-hour meter (handbook)--a watt-hour meter with two registers so that the off-peak and on-peak energy (kilowatt-hours) will be recorded on separate dials. The switch from one register to the other is controlled by an internal time switch or by an external signal that may be actuated from a local device or from a device located at a remote location. Carry-over may be accomplished by battery, spring storage, or photo-cell synchronization.

dry-bulb temperature--see temperature.

effective degree-hour--see temperature.

electronic register (handbook)--a solid state memory to which a magnetic tape recorder can be attached to allow both a solid state and a tape record.

encoder (handbook)--a device that can convert the meter reading into a form suitable for communicating to a remote central location.

energy--the kilowatt-hours supplied to or used by an individual customer, average customer, group of customers, or class of service. Energy use may be determined by measurement or by calculation.

feeder (EEI)--an electric line for supplying electric energy within an electric service area or subarea.

frequency distribution--a systematic arrangement of statistical data in tabular or graphic form that shows the division of the values of a variable (customers, hours, etc.) into class intervals (e.g., energy use, demands) and that indicates the frequencies or relative frequencies (in numbers or percent) that fall within each of the intervals.

cumulative frequency distribution--a summation of frequency distributions usually beginning with the first class interval in a distribution and expressed as "less than" the upper limit of the intervals accumulated. The cumulatives represent the number of items whose frequency is less than the limit to which the cumulatives apply.

normal (Gaussian) distribution--a theoretical frequency distribution used in statistics that is bell-shaped, symmetrical and of infinite extent. The frequencies of many business statistics are asymmetric; however, such skewed distributions can sometimes be made to approximate normal frequency distributions by plotting their frequencies on the logarithms of the class limits instead of on the measures themselves. Such distributions are known as logarithmic normal distributions.

ogive--the graph of a cumulative frequency distribution.

giga--prefix meaning billion.

group--a sample forming a recognizable unit based on a common characteristic determined by the type of study involved, e.g., class of service, size of demand or energy use, load factor.

group demand--see demand.

individual customer's maximum demand--see demand.

industrial--a classification covering service for industrial use. Unless otherwise defined, industrial refers to those establishments identified in the Standard Industrial Classification Manual, Office of Management and Budget, 1972, as falling in the following divisions:

B	Major Groups 10-14	mining
D	Major Groups 20-39	manufacturing
E	Major Groups 40-49	transportation, communication, electric, gas, and sanitary services.

and all parts of Division J, Public Administration, classified as industrial in the two-digit classification.

integrated demand--see demand

kilo--prefix meaning thousand.

kilovolt-ampere demand--see demand

large light and power--a customer, sales, or revenue classification covering electric energy supplied to customers for commercial and industrial purposes. This classification includes customers whose demand exceeds 50 kW, and/or whose annual energy use exceeds 100,000 kWh.

light emitting diode (handbook)--a device for testing an electronic register.

load--the amount of power delivered or received at a given point over a specific time interval. It may apply to a total system, a part of a system, an individual customer, or group of customers.

load characteristics--collectively, all or part of the features of the electric service rendered, including: energy use, demand, time of occurrence, coincidence factor, demand factor, load factor, and similar derivable relationships.

load curve--as applied to a customer, group of customers, class or system, a load curve is a curve (usually plotted point to point) showing the power supplied during a specified period of time as plotted against the time of occurrence. Demands may be expressed in watts, kilowatts, kilovolt-amperes, or as a percentage of the average or maximum load during the period in question. Time units may be 15, 30, or 60 min. Load curves normally cover a 24-hour period for a specific or average day and are plotted midnight to midnight.

load diversity--the variation between the sum of the peaks of two or more individual loads and the peak of their combined load.

load duration curve (FERC)--a curve showing the total time (or percentage of time) within a specified period during which the load equaled or exceeded the power values shown.

load occurrence curve--a curve relating load in percent of annual peak to cumulative energy output in percent of annual total.

load factor--the ratio, in percent, of the average demand over a designated period of time to the maximum demand occurring in that period. Load factor is derived by the formula:

$$\frac{(\text{kWh in period}) \times 100}{(\text{max demand in kW}) \times (\text{hr in period})} = \text{load factor (in percent)}$$

Load factor may refer to customer, appliance, group, class, or system loads and may cover a daily, weekly, monthly, or annual period.

load research--an activity embracing the measurement and study of the characteristics of electric loads to provide complete and reliable data on the general behavior of the load characteristics of the more important components of loads served by the electric utility industry.

load survey--the various steps and processes generally used in making load tests. It encompasses the selection of loads to be studied, the method of collecting and analyzing the load data, and the presentation of the load data in a useful form.

magnetic tape recorder (handbook)--a magnetic recording device that uses one or more pulse initiators that are attached to meters. Pulses are generated proportional to load. These pulses are stored on one or more data tracks of a magnetic tape; on a remaining tape track, a time pulse, generated every 15, 30, or 60 min by the recorder, is marked at appropriate intervals to properly space the pulse data.

magnetic tape translation system (handbook)--a system that reads magnetic tape pulse information from magnetic tape meter tapes and arranges the data, generally on magnetic tape such as 9-track, for direct input to a computer for conversion to engineering units and for use in combination with output from similar magnetic tape meters.

manufacturing--a classification covering service for manufacturing uses, identified as Division D in the Standard Industrial Classification Manual.

major appliance--electrical appliance having a high energy use and relatively high connected load, normally occupying a fixed location on a customer's premises, e.g., clothes dryer, range, refrigerator, freezer, air conditioner, and water heater.

mass sampling--see sampling techniques.

maximum demand--see demand.

mean daily temperature--see temperature.

mega--metric prefix meaning million.

multirate watt-hour meter (handbook)--a watt-hour meter having more than one set of energy recording registers. This could be a dual-rate or differential register meter.

noncoincident maximum demand--see demand.

nonmanufacturing--a classification covering all major groups in the Standard Industrial Classification Manual, Bureau of the Budget, 1967, except those identified as manufacturing, Division D, and part of Division I. See "manufacturing."

off-peak (EEI)--energy supplied during periods of relatively low system demand as specified by the supplier.

ohm (handbook)--the unit of resistance in electric currents.

on-peak demand register (handbook)--a register that will record both the total energy used and the maximum peak demand. The demand recording is controlled by a solenoid-operated demand gear train that may be actuated locally or remotely.

output, system (EEI)--net energy generated by the system's own plants plus energy received from other systems minus energy delivered to other systems.

peak demand--see demand.

peak responsibility--the load of an appliance, customer, group of customers, class, or part of a system coincident (in time) with the peak demand of the group, class, or system.

peak responsibility factor (contribution ratio)--the ratio of the average demand over a designated period of time, of an appliance, customer, group of customers, class, or part of a system to a specific peak responsibility of the appliance, customer, group of customers, class, or part of a system.

peak splitting (handbook)--the splitting of peak load over two adjacent demand intervals.

power factor (EEI)--the ratio of real power (watts) to apparent power (volt-amperes) for any given load and time; usually expressed as a percentage.

power line carrier (handbook)--a communication system using the utility power line as the primary element in the communication link. Frequencies may range from 8 kHz to 200 kHz and above. The system can be unidirectional or bidirectional and power levels are normally low (in the 1-W to 20-W range).

pulse initiator (handbook)--a device for transforming demand levels into pulses that may be printed on recording tape.

Q hour (handbook)--reactive voltampere-hour; voltampere is a unit of apparent power.

recorder (handbook)--a device for recording customer electricity demands over prespecified intervals on a permanent readable medium.

remote meter reading system (handbook)--a system capable of reading a meter (watt-hour, demand, gas, water, etc.) and presenting the data by direct cable to a local collection point. Field personnel collect these data for central processing.

residential (EEI)--a customer, sales, or revenue classification covering electric energy supplied for residential (household) purposes.

ripple control (handbook)--a combination of equipment installed within an electrical network to superimpose on the power line a frequency/time-coded message interpretable as command signals by remotely located receiver relay devices. The frequency of ripple control systems is usually in the audio range (300 Hz) and power levels are relatively high (typically up to 1% of system power).

rural (EEI)--a rate classification covering electric energy supplied to rural and farm customers (under distinct rural rates).

sampling methods

area method of testing--testing of a group of customers within a contained area at a common energy supply point to determine diversified load characteristics. For load research purposes, customers within the test area should be relatively homogeneous as to class of service and size.

individual selective sampling or stratified sampling--the selection of sufficiently large random samples from each group or subgroup of the universe under consideration to give statistically acceptable results for the load characteristics of the group or subgroup. The proportion of each group or subgroup to the universe as a whole may vary over a wide range.

mass sampling--the selection of a random sample from the total universe under consideration. The sample size should be sufficiently large to give statistically reliable results for the universe; it may not give statistically stable results for subgroups of the universe.

random sample--a sample drawn in such a way as to insure that each and every sample unit has the same chance of being selected.

test sample--the total group of customers or appliances chosen for test by approved methods of sample selection.

solid state recording (handbook)--process by which customer demand pulses are read into a solid state memory instead of onto recording tape.

status flag (handbook)--an entry on computer tape that informs the user of the editing history of any datum.

service area (EEI)--the territory in which a utility is required or has the right to supply electric service to ultimate customers.

stratification (handbook)--the process by which a population is divided into nonoverlapping segments called strata that together compose the entire population.

survey period--the entire period during which the load characteristics are studied.

system maximum demand--see demand.

system peak demand--see demand.

tape verifier (handbook)--a device for confirming whether a recording tape is in usable condition.

temperature--

degree-day (cooling)--(a) A unit measuring the extent to which the outdoor mean daily dry-bulb temperature rises above an assumed base. One degree-day is counted for each degree of excess over the assumed base for each calendar day on which such excess occurs. (b) A unit representing the excess of the daily temperature-humidity index (THI) over an assumed base. The daily average of 24 hourly values of dry-bulb temperatures and dew point readings are used in the equation. One degree-day is counted for each degree of excess over the assumed base for each calendar day on which such an excess occurs. (c) Degree-quarter-day (cooling) is a unit representing the excess of the average of four temperature-humidity index (THI) values, taken at six-hour intervals, over an assumed base. One degree-day is counted for each degree of excess over the assumed base for each calendar day on which such excess occurs.

degree-day (heating)--a unit measuring the extent by which the outdoor mean daily dry-bulb temperature falls below an assumed base. One degree-day is counted for each degree of deficiency below the assumed base for each calendar day on which such deficiency occurs.

degree-hour (cooling)--(a) a unit measuring the extent to which the outdoor hourly temperature rises above an assumed base. One degree-hour is counted for each degree of excess over the assumed base for each hour in which such excess occurs. (b) A unit measuring the extent to which the hourly effective degree-hour rises above an assumed base. One degree-hour is counted for each degree of excess over the assumed base for each hour in which such excess occurs.

degree-hour (heating)--a unit measuring the extent to which the outdoor hourly temperature falls below an assumed base. One degree-hour is counted for each degree of deficiency below the assumed base for each hour in which such deficiency occurs.

design temperature difference--in heat loss calculations, the difference between potential minimum outdoor temperature during the heating season and normal indoor temperature maintained by the customer. The value varies from area to area throughout the United States.

dry bulb--temperature indicated by a thermometer with the bulb dry; usually in degrees Fahrenheit.

effective degree-hour (cooling)--an empirical index of relative air cooling requirements. Unless otherwise determined, it can be calculated by applying a weight of 1.0 to the dry-bulb degree-hours and 2.0 to the wet-bulb degree-hours for a specified period (day, week, month, or cooling season).

mean daily temperature--the average of the high and low temperatures recorded during a 24-hour period taken from midnight to midnight.

temperature-humidity index--a term used by the United States Weather Bureau to indicate the combination of temperature and air moisture that causes diverse sensations of comfort and discomfort in human beings. The temperature-humidity index (THI) values (dry bulb--dew point calculation) are derived from the formula: $THI = 0.55t_d + 0.2t_{tp} + 17.5$, where t_d is the hourly dry-bulb temperature and t_{tp} is the dew point temperature reading. Other formulas may be used, depending on the data available. Based on dry-bulb (t_d) and wet-bulb (t_w) temperatures, $THI = 0.4(t_d + t_w) + 15.0$. Based on dry-bulb temperature (t_d) and relative humidity (RH), $THI = t_d - (0.55 - 0.55\ RH)(t_d - 58.0)$.

wet bulb--the temperature indicated by a thermometer with the bulb covered by a wet wick when in relative motion to the air (sling psychrometer). Used in connection with cooling only.

temperature-humidity index--see temperature.

tera--metric prefix meaning trillion.

test period--the period during which actual measurements of the load under study are being made. Specific dates for the test periods of both energy use and demand measurements should be indicated.

three-rate watt-hour meter (handbook)--a watt-hour meter with three registers to allow the off-peak energy to be recorded on one dial and the on-peak for two different on-peak periods to be recorded on the other two dials. The control of the recording system is by an internal time switch or external signal that may be actuated locally or remotely.

time-of-day metering (handbook)--a method or system for recording kilowatt-hours consumed or a maximum demand established during both a specified period of time (on-peak) and the entire day.

translator (handbook)--a device for reading pulses on magnetic tape and transferring the demand data to computer-compatible tape.

transponder (handbook)--a passive device that stores a signal and, upon interrogation by a specific radio frequency to which it is tuned, releases the signal as a reflected wave.

two-way communications system (handbook)--see automatic meter reading system.

use--energy use in kilowatt-hours; may be hourly, daily, weekly, monthly, bimonthly, quarterly, or annual.

volt--the unit of electromotive force which, if steadily applied, will cause a current of one ampere to flow through a conductor whose resistance is one ohm.

volt-ampere--the mathematical product of one volt and one ampere; in a direct current, it is equal to one watt.

watt--the unit of electric power equivalent to one ampere flowing under a pressure of one volt at unity power factor.

watt-hour--the unit of electric energy expended in one hour when the power is one watt.

wet bulb--see temperature.

GLOSSARY OF STATISTICAL TERMS

allocation procedure--a procedure by which a predetermined number of sample customers is allocated to several strata. Allocation is proportional when each stratum's share of the sample total equals its share of the population total. Allocation is optimal (or Neyman optimal) when the overall sample variance is minimized.

bias--a condition that exists when the expected value of a sample statistic is not equal to the population parameter it seeks to estimate.

bandwidth--an interval of half-length b centered about a point x. It extends from x - b to x + b.

confidence--a statistical measure of the certainty that a sample statistic will fall within a prespecified bandwidth of the expected value of the population parameter it attempts to estimate.

continuous variable--a variable of stratification or analysis that may take all values in an interval and can be represented by a smooth curve (see also discrete variable).

correlation coefficient--a statistic that measures the degree to which two variables increase and decrease together. Correlation coefficients can be between -1 and 1. A positive correlation coefficient indicates that one variable increases (and decreases) when the other does. A negative correlation coefficient indicates that one variable increases when the other decreases. Population correlation coefficients (written ρ) are obtained by taking the ratio of the population covariance between two variables to the products of the two variables' population standard deviations. Sample correlation coefficients (written r) are obtained by taking the ratio of the sample covariance between two variables to the product of the two variables' sample standard deviations.

covariance--a statistic that measures the degree to which two variables increase and decrease together. A positive covariance indicates that the two variables increase and decrease simultaneously. A negative covariance indicates that one variable increases while the other decreases. A population covariance σ_{xy} between two variables X and Y is obtained using the formula

$$\sigma_{xy} = \sum_{i=1}^{N} (X_i - \mu_x)(Y_i - \mu_y)/N$$

where:

σ_{xy} = population covariance between X and Y,

μ_x = expected value of X,

μ_y = expected value of Y, and

N = size of population.

A sample covariance s_{xy} between two variables X and Y is obtained:

$$s_{xy} = \sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})/(n - 1)$$

where:

s_{xy} = sample covariance between X and Y,

$\bar{X}$ = sample mean of X,

$\bar{Y}$ = sample mean of Y, and

n = size of sample.

discrete variable--a variable of stratification or analysis that may only have integer values over an interval (also see continuous variable).

domains of analysis--nonoverlapping segments of a sample population that together compose the entire population and that serve as the basis for organizing the analytical framework.

expected value--the magnitude that an observed parameter is expected to have. The chances of the observed parameter being greater than or less than its expected value are equal.

extrapolation--the procedure by which sample average statistics are "blown up" to obtain group totals.

interpolation--the procedure by which a missing data gap is edited by constructing a functional relationship between observed data before and after the gap.

linear regression (or ordinary least squares, least squares)--a mathematical procedure by which one dependent variable is represented as a linear function of one or more independent variables.

mean (or sample mean)--a sample statistic equal to the average of all sample observations. Its expected value is the same as the expected value of the corresponding population parameter. The mean of a variable X is calculated as:

$$\bar{X} = \sum_{i=1}^{n} X_i/n$$

where:

n = sample size, and

$\bar{X}$ = sample mean of variable X.

Neyman optimal allocation--see allocation.

optimal allocation--see allocation.

parameter (or population parameter)--an observable and measureable attribute, e.g., the kilowatt demands of a population that the researcher is studying.

population (or universe, target population)--a category of electricity uses (appliance, customer, class) about which the load researcher attempts to measure some relevant parameters, usually with a survey sample.

primary sampling unit--the basic unit of observation in a survey sample.

probability sample--see sample.

proportional allocation--see allocation.

randomization--the process of selecting a random sample or stratum.

reliability--an estimate of a sample statistic's precision; the ratio of a prespecified bandwidth to the sample statistical mean. Researchers often express their confidence that the sample statistic is observed with a certain degree of reliability, which means they designate how certain they are that the sample mean lies within a designated bandwidth of its corresponding expected value.

sample--a subset of an entire population, which a researcher surveys in order to obtain information on the entire population. Also see sampling methods.

probability sample--a sample where every customer in the population has a known probability of being included.

random sample--a probability sample where all probabilities of inclusion are equal.

sampling methods--procedures for designing a sample.

cluster sampling--a sampling procedure where groups of customers are selected for inclusion in the sample. This is contrasted to methods that select sample customers one at a time. Though customers are selected collectively, they are metered individually.

group metering--a sampling procedure where customers are metered collectively rather than individually. Customers are selected and metered collectively.

simple random sampling--a sampling procedure where the sample is not stratified and the sample customers are randomly selected.

stratified random sampling--a sampling procedure where the population is first divided into nonoverlapping segments called strata and customers are selected for inclusion in each stratum; customers within any one stratum are randomly selected. Strata may or may not be represented proportional to their share in the population.

two-phase sampling--a sampling procedure where a first-stage survey assesses important attributes of the population and a second-stage survey incorporates the first-stage analysis in its stratification.

statistic--an obtained measurement on a sample, used to estimate a population parameter.

statistical stratification--see stratification.

stratification--the division of a population into several nonoverlapping subgroups called strata, which together compose the entire population and which serve as the organizing framework for sample design. "Subjective" stratification defines these strata along the guidelines of a researcher's particular interest while "statistical" stratification defines these strata primarily to minimize the overall sample variance.

standard deviation--a measure of dispersal of a population variable about its expected value or a sample variable about its mean. The population standard deviation is the square root of the population variance, while the sample standard deviation is the square root of the sample variance.

subjective stratification--see stratification.

universe--see population.

variance--a measure of dispersal of a population variable about its expected value or a sample variable about its mean. The population variance, ^{2}, is measured as:

$$\sigma^2 = \sum_{i=1}^{N} (X_i - \mu)^2/N$$

where:

N = size of population, and

μ = expected value of X.

The sample variance, s^2, is measured as:

$$s^2 = \sum_{i=1}^{n} (X_i - \bar{X})^2/(n - 1)$$

where:

n = sample size, and

$\bar{X}$ = sample mean of X.

BIBLIOGRAPHY*

The references in this bibliography can be classified as follows:

Topic	Elementary Discussion	Advanced Discussion
General overview	12, 15, 20	12, 20
Load research objectives		
Rate design	2, 5, 21, 23	2, 5, 21, 23
Load forecasting	16	16
System design	1, 27	1, 27
Load management	18, 21, 25	18, 21, 25
General statistics	4, 7, 11	17
Regression techniques	19, 28	13, 19, 28
Sample design	3, 26	6, 8, 10, 14
Compendium	9, 22, 24	9, 22, 24

1. *A Description of the National Electricity Supply Optimization Model*, National Economic Research Associates, Inc. (March 1976).

2. *A Framework for Marginal Cost-Based Time-Differentiated Pricing in the United States*, prepared by National Economic Research Associates for Electric Utility Rate Design Study (Feb. 1976).

3. *A Million Random Digits*, Rand Corp., The Free Press, Glencoe, Ill. (1955)

4. *Applied Statistics in Load Research,* Vols. 1 and 2, Association of Edison Illuminating Companies, New York City (1964 and 1965).

5. Bary, C., *Operational Economics of Electric Utilities*, Columbia University Press, New York City (1963).

6. Cochran, W.G., *Sampling Techniques*, John Wiley and Sons, Inc., New York City (1964).

7. Crow, E.L., F.A. Davis, and M.W. Maxfield, *Statistics Manual*, Dover Publications, Inc., New York City (1976).

8. Deming, W.E., *Some Theory of Sampling*, John Wiley and Sons, Inc., New York City (1950).

9. *Elements of Load*, Potomac Electric Power Company, Rate Department, Washington, D.C. (June 1977).

*Reports prepared as part of the Electric Utility Rate Design Study are available from: Rate Design Studies, P.O. Box 10412, Palo Alto, California 94303.

10. Hansen, M.H., W.N. Hurwitz, and W.G. Madow, *Sample Survey Methods and Theory*, John Wiley and Sons, Inc., New York City (1953).

11. Hoel, P.G., *Introduction to Mathematical Statistics*, John Wiley and Sons, Inc., New York City (1966).

12. Houston, J., *Procedures for Implementing Load Research*, unpublished manuscript, Southern Services, Inc., Atlanta.

13. Johnston, J., *Econometric Methods*, McGraw-Hill, Inc., New York City (1972).

14. Kish, L., *Survey Sampling*, John Wiley and Sons, Inc., New York City (1965).

15. *Manual of Procedure for Load Surveys*, Association of Edison Illuminating Companies, New York City (1961).

16. *Model for Long Range Forecasting of Electric Energy and Demand*, Battelle Columbus Laboratories and New England Power Pool (1976).

17. Morrison, D.F., *Multivariate Statistical Methods*, McGraw-Hill Book Co., New York City (1976).

18. *Opportunities and Incentives for Electric Utility Load Management*, prepared by Gordian Associates for Federal Energy Administration (1976).

19. Pindyck, R.S., and D.L. Rubinfeld, *Econometric Models and Economic Forecasts*, McGraw Hill Book Co., New York City (1976).

20. *Proceedings of the 1979 Load Research Seminar*, Association of Edison Illuminating Companies, Load Research Committee (July 1979).

21. *Rate Design and Load Control*, Electric Utility Rate Design Study (Nov. 1977).

22. *Rate Design Study: Load Research,* Vols. I and II, prepared by Gilbert Associates, Inc., for Electric Utility Rate Design Study (Nov. 1979).

23. *Reference Manual and Procedures for Implementing PURPA*, Electric Utility Rate Design Study (March 1979).

24. Reznek, B., *An Annotated Compilation of the Sources of Information Related to the Usage of Electricity in Non-Industrial Applications*, U.S. Department of Commerce (July 1978).

25. Schaefer, J.C., *Equipment for Load Management*, Electric Utility Rate Design Study (Oct. 1979).

26. Slonim, M.J., *Sampling: A Quick Reliable Guide to Practical Statistics*, Simon and Schuster, Inc., New York City (1966).

27. Turvey, R., *Optimal Pricing and Investment in Electricity Supply*, George Allen and Unwin Ltd., London (1968).

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APPENDIX A

AEIC STANDARDS FOR PREPARING LOAD RESEARCH REPORTS*

*Only the first 13 pages of the AEIC standards are reproduced here. However, readers should note that these pages contain references to pages 14-49 of the standards. Cross references to the first 13 pages have been renumbered for the reader's convenience.

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STANDARDS FOR PREPARING REPORTS OF THE LOAD RESEARCH COMMITTEE*

FORMAT OF THE ANNUAL REPORT

General

The Annual Report of the Load Research Committee consists of reports prepared by five standing subcommittees and by special study groups assigned to investigate particular aspects of load research. The order of the subcommittee reports is determined by the section number assigned to each subcommittee. Each subcommittee is also assigned a letter designation for charts and tables contained in their sections.

Annual Report Section	Chart and Table Letter Designation	Subcommittee Title
1	A	Class Load Studies
2	B	Specific Loads
3	C	Load Research Planning
4	D	Load Research Methods
5	E	Steering

Special reports follow those of the regular subcommittees. Dissenting opinions, if any, are appended to the appropriate section.

The body of the report is preceded by a statement regarding the policy on use of annual reports, a table of contents, a foreward, and a list of members. A standard form of cover, adopted by the Association for the separately printed committee reports, identifies the committee preparing the report and indicates the administrative year in which the report is made. The report of the Load Research Committee is incorporated in the Annual Minutes of the Association.

Table of Contents

The Contents lists the major topics covered in the Report: Foreword, Members, and Subcommittee Reports by section number and title. Within each section, major subsections and appendices are identified. The appendix subheadings include the name of the company preparing the study and a short description of the material covered. In general, the Contents is a composite of the tables of contents covering the subcommittee reports as submitted to the Chairman of the Load Research Committee.

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* Report of the Load Research Methods Subcommittee: Ronald Daniels, chairman, R. A. Abdoo, A. J. Baldwin, Lois E. Brandenburg, C. T. Loshing, and R. C. Williams.

Foreword

The Foreword of the Annual Report is written by the Chairman of the Committee. It describes briefly the material contained in the Annual Report and points out significant conclusions found in the subcommittee reports. Other items that may appropriately be included concern projects in progress, pamphlets printed by the Committee during the administrative year, retirements, new members and acknowledgments to member and nonmember companies contributing to the Report.

List of Members

Committee members who have served in the administrative year are listed on a separate page. The list is alphabetical by surname, with initials following, and indicates the company affiliation of each member. The words "Chairman" and "Vice Chairman" follow the names of those serving in these capacities. Advisory members are so designated.

Body of Report

The body of the Annual Report is comprised of one or more reports of the standing subcommittees or of special study groups. These reports may involve customer or appliance load characteristics or other matters associated with load research activities.

Reports on load characteristics are typical of those prepared by the Class Load Studies Subcommittee, and the Specific Loads Subcommittee. Reports on other matters are typified by those of the Load Research Methods, Load Research Planning, and Steering Subcommittees.

Reports of the subcommittee chairmen are abstracts of the detailed studies appearing as appendices. The material is generally presented under two topic headings: Scope and Conclusions. Scope covers a brief description of each appendix, including the company preparing the study and the nature of the data presented. Conclusions summarize the principal results discussed in the Summary of Major Findings sections of the appendices. Conclusions may also include brief tables comparing pertinent data from various appendices. When appropriate, the subcommittee chairman may suggest applications of the data presented and areas for further study.

Each subcommittee report is identified by an appropriate section number and title. The title is footnoted with an asterisk identifying the subcommittee members.

Appendices

The appendices of each subcommittee report are digests of studies on class or appliance loads or on other subjects related to load research and its applications. The digests consist of thorough but concise descriptive statements and such tables and charts as are necessary to support the observations. Complicated formulas, mathematical computations, and specialized dissertations are usually found in the appendices rather than in the body of a subcommittee report.

Appendices concerned with load characteristics generally consist of four major divisions: Purpose of Study, Summary of Major Findings, Test Procedure, and Discussion of Data.

The Purpose of Study describes briefly why the study was originated and suggests general applications of the test results.

The Summary of Major Findings highlights the basic results of the load research and states such conclusions and comments as may reasonably be drawn from the test data.

Test Procedure includes: (1) size of sample, (2) size of universe from which the sample was drawn, (3) method of sample selection, (4) characteristics of sample, and (5) duration and method of testing. The amount of detail should be governed by its pertinence to the analysis of the test results. When a new or unique method of sampling or testing is used, somewhat more than a minimum description is warranted to enable future load research investigations to take advantage of them.

The Discussion of Data outlines the various charts and tables included as part of the appendix, discusses in detail formulas, "peculiar" terms, unusual findings, adjustments made in test results and other specific information necessary to interpret the data.

No standard form is established for papers on matters other than load characteristics. In general, however, such appendices should include: Purpose of Study, Method of Investigation, and Discussion of Major Findings.

Reports on time-of-use surveys and experiments should follow the format established herein. There are, however, special considerations to be given to the additional information and analysis methods required in such studies. Appendix E discusses in detail the elements needed to produce a useful report.

All appendices are prepared by or under the direction of committee members. Studies contributed by member companies represented on the Committee will be credited to the company representative. Each appendix should be captioned and footnoted.

Studies from member companies not represented on the Committee and from nonmember sources are prepared as appendices by subcommittee members as assigned by the subcommittee chairmen. Each appendix should be captioned and footnoted.

The authors of such appendices must clear them with the contributing companies and secure approvals for their use by the Committee.

When a study is prepared by an author from a company not represented on the Load Research Committee, the subcommittee chairman will make available to him a copy of the Standards for Preparing Reports as a guide to preparing the digest.

PREPARATION OF SUBCOMMITTEE REPORTS AND APPENDICES

General

The objective of a report is to present information in a clear and concise manner. A well-written report will cover pertinent data and conclusions in a minimum of words, but in sufficient detail to enable the reader to obtain all significant data available from the test. The author of any appendix or subcommittee report has considerable latitude in his approach and in the material included. However, format and terminology should strive for uniformity and consistency with other reports on the same or related subjects.

Conformance to prescribed formats and rules applicable to the preparation of subcommittee reports, appendices, tables, and charts will expedite the editing and printing of the Annual Report.

Style and Terminology for the Writer

1. Be accurate in terminology, spelling, punctuation, titles, mathematical computations, and sources of data.

2. Write in the third person. Use present tense to report present facts. Use simple terms and expressions.

3. Use standard abbreviations and symbols in text, tables, and charts, as shown in Appendix A, pages 17-19.

4. Consult a standard dictionary for spellings and definitions and for abbreviations and symbols not commonly used in load research 1/.

   A Glossary of Load Research Terms is included as Appendix B, pages 20-28.

5. Punctuate and hyphenate properly. When in doubt, consult a standard guide, e.g., the terms in Appendix A and Webster's New Collegiate Dictionary.

6. Avoid commercialism, lengthy quotations, foreign words, coined words, and colloquialisms. Define technical and unusual terms. Explain terminology that may be peculiar to the company preparing the study, e.g., General Service Rate, off-peak hours.

7. Give specific times, dates, and values whenever possible. Identify estimates.

8. In the text, avoid capitalization except for initial letters of proper names, organizations, etc. Initial capitals should also be used for Annual Report (of the Association), Subcommittee Chairman and Company

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1/ For additional references see pg. 125, point 8 of this report.

(when a specific person, position or company is intended). As a general rule, area identifications are capitalized only when referring to a specific geographic division, e.g., the West North Central Region (as a specific EEI defined region).

9. Avoid the use of capitals, italics or underlining in the text for emphasis.

10. Use electrical terms properly. Write nonmanufacturing, noncoincident and kilowatthour as single words.

11. Be precise in the identification of data, particularly with respect to demand and energy use measurements. Specify the demand interval (e.g., instantaneous, 30-minute integrated), the type of demand (average, group maximum, noncoincident maximum) and the specific dates of the measurements if available. All data should be obtained in the same test period and with the same demand interval. Exceptions should be clearly indicated.

Footnotes

Footnotes are designated by superscript numerals in a bracket, except that an asterisk is used on the first page of each subcommiteee report to identify the subcommittee membership, and on the first page of each appendix to identify the author and/or representative preparing the study. Footnotes are placed at the bottom of the page and separated from the text by two spaces, a solid line 1 inch in length, and two more spaces. The first footnote on each page of the text is designated as: [1/] The reference notation is typed on the line with the footnote entry, as shown below.

References

When only a few references are cited, they should either be included in parentheses in the text or treated as footnotes. When there are numerous references, they are identified by Arabic numerals in the text listed in numerical order at the end of the paper. If references are general, they should be listed alphabetically by author at the end of the report.

In a footnote, the format for references to books, articles, and pamphlets is as follows:

Author's name with given name or initials first
Title of article, section, or chapter (if appropriate)
Title of book, magazine, or pamphlet
Place of publication, publisher's name, date of publication,
 and page reference (for books and pamphlets)
Volume number, date, and page reference (for articles)

1/ See pg. 122 for rules applicable to footnotes for tables.

Illustrative references are shown below:

For a book:

(1) C. W. Bary, Operational Economics of Electric Utilities. New York. Columbia University Press, 1963, p.94.

For a magazine article:

(2) A. J. Stegeman, "16th Annual Electrical Industry Forecast", Electrical World, Volume 164, No. 12, September 20, 1965, pp. 105-120.

For a pamphlet:

(3) Applied Statistics in Load Research, Volume II. New York: Association of Edison Illuminating Companies, June 1965, p. 202.

When references are listed as bibliography rather than as footnotes, the same format applies except that the last name of the author is shown first and references are arranged alphabetically.

Use of Numerals

1. Use numerals for all quantities exceeding ten, except as otherwise specified in the following items.

2. Spell out in the text all fractions having denominators of ten or less, such as, one-half and one-tenth, unless such fractions are part of a mixed number. Mixed numbers should be typed in the form 8 1/2 rather than 8½. In mathematical expressions, use parentheses to avoid ambiquity, e.g., (1/2)(a - b), rather than 1/2(a - b).

3. Use numerals for all quantities in a series when any one quantity in the series is greater than ten or in which the use of numerals is required by the application of any other rule.

4. Use numerals for all decimal quantities. In a series of numbers or for numbers of similar nature, decimal digits should conform, even if the decimal is zero, e.g., 10.6, 13.0, 0.3. Show significant decimals only; do not imply undue accuracy.

5. Use numerals for all units of measurement, such as 30 years or 60 hertz.

6. In the text, the symbol (%) and abbreviations for such measurements as kilowatts, gallons, inches, and feet may be used following a numeral, e.g., 60.3%, 45 kW, 60 gal. When used as a separate word, the measurement is spelled out.

7. Demand factors, coincidence factors, load factors, and appliance saturations are expressed as percentages rather than as ratios.

8. Use commas to indicate thousands, millions, etc., in numbers of 1,000 or more.

9. Tabular data are aligned on decimals except when such alignment seriously affects the appearance or legibility of a table.

10. If necessary to start a sentence with a numeral, the numeral must be spelled out.

11. Use Arabic numerals for dates, page numbers, table, chart and figure numbers, tabular listings, and section numbers.

Instructions for Typist

1. Type manuscripts on good quality 8 1/2 x 11 inch paper, with 1 inch margins at the top, bottom, and sides.

2. The manuscript should be single spaced, double spaced between paragraphs, and triple spaced between major topics.

3. Center and capitalize appendix and section designations and titles of reports. Triple space between section designations and title of reports; double space between appendix designations and title of report, then triple before text of appendix.

4. Begin major topic headings at the left margin, typed in upper and lower case, and underlined.

5. Subheadings should be indented five spaces, typed in upper and lower case, and underlined.

6. Extracts are single spaced and indented on both sides.

7. Footnotes are single spaced.

8. Series of numbered statements are typed as separate paragraphs with margins as per this sample.

9. Page numbers on original copy are eliminated; however, a numbered copy should be provided to identify the page sequence. Pages will be renumbered as appropriate by the committee secretary.

10. Clearly differentiate between a hyphen and a dash. The preferred form is to use a hyphen without spacing when a hyphen is intended, as in 12-month period or all-electric home. Use two hyphens to indicate that a dash is intended, e.g., standard water heaters -- under 65 gallons.

11. Use rules under Style and Terminology for the Writer and Use of Numerals as applicable. For tables, charts, and illustrations, use prescribed format and typing rules on pp. 120-124. The charts and tables in these Standards may be used as guides.

TABLES, CHARTS, AND ILLUSTRATIONS

Definition of Terms

The Load Research Committee defines tables, charts, and illustrations as follows:

A table is a compact arrangement of related facts and figures in an orderly sequence, usually in lines and columns.

A chart is a graphic representation of the mathematical relationship between two or more variables. The relationship may be shown as a curve, a series of dots, straight lines or bars. When more than one chart appears on a page under one main title, the individual charts are designated as figures unless otherwise identified.

An illustration is a photograph, diagram or other presentation falling beyond the scope of the definition of table or chart. Since use of illustrations is infrequent, no general rules are established except that any illustration submitted for reproduction should be a clear, black and white print. Appropriate identifying captions should accompany the illustrations.

Titles of Tables and Charts

Tables and charts are assigned numbers by the subcommittee with the appropriate letter prefix, e.g., TABLE A-1, TABLE A-2, CHART B-1, CHART B-2. However, when the tables or charts contain several subgroupings of a class the assigned numbering, by the subcommittee, will be as follows: CHART B-3, 0 - 500 kWh per Month, CHART B-3 CONTINUED, 501 - 1,000 kWh per Month. A permanently assigned letter prefix identifies the charts and tables of each standing subcommittee:

A - Class Load Studies
B - Specific Loads
C - Load Research Planning
D - Load Research Methods
E - Steering

The latter four subcommittees, whose reports may contain studies on more than one subject, may use a second letter to identify the subject of the chart or table. The second letter is assigned by the subcommittee chairman. For example, a study of water heaters prepared by the Specific Loads Subcommittee could have its charts and tables numbered CHART BW-1, TABLE BW-1, etc.

Each table and chart is identified with a brief descriptive title indicating the type of data shown, the period of the test and the geographic location. The location should be an area designation, e.g., city or state, rather than the company supplying the data. The letter prefix indicates the general type of load, hence, in tables, and charts identified with A or B, the descriptive words Class Load Study or Specific Loads need not be in the title unless needed for clarity.

Table and chart numbers, provided by the subcommittee, are typed entirely in capitals: TABLE A-1, CHART C-2. The descriptive portion of the title is typed with initial capitals for each word (except articles, conjunctions and prepositions). Titles of tables should be in the same type face as the tabular data. Chart titles should be typed rather than lettered.

Format and Typing of Tables

Tables of not more than 12 lines may be included in the text, but must appear entirely on one page. Such tables do not require a title or identification number; however, line and column headings should be concise and clear.

Larger tables should be typed on separate 8 1/2 x 11 inch paper or reduced to this size. Use more than one page if the reduction would not be perfectly legible when reduced to the final printed size.

Tables that are computer-generated are acceptable as long as they meet the required 1 inch margin on all four sides including table number and title.

The original tables should be in a clear type on a good quality bond. The overall size of the typed copy should be in proportion to the final printed page. Tables printed upright or sideways should allow at least a 1 inch margin on all four sides including table number and title.

For satisfactory legibility when reduced, tables printed sideways should not exceed 140 tabular data characters, including spaces, in width and 35 lines in depth. These restrictions include column headings, but exclude table number and title which may add up to five lines of type.

In general, the original tables should be no more than twice the size of the final printed copy. Complete titles and table numbers should be shown at the top of each table.

In tables, the lines of data are numbered (with no period following the numeral) from top to bottom at the left of the page. When more than one line is required for the description, the second line is indented one space and is not numbered. Numbers may be omitted if the lines are identified as customer numbers or months. Abbreviations may be used to equalize the length of lines.

Descriptive items in the left column are written in lower case, except for initial letters of first words and proper nouns. Abbreviations and symbols are written as shown in Appendix A. Subordinate items are indented five spaces under main headings and subheadings.

Column headings are set off from the data by underlining. Initial letters of all words (except conjunctions and prepositions) are capitalized. Placement of numbers, dates, and other data should minimize the width of columns and present a balanced systematic appearance.

In both line and column descriptions, the unit of measurement is set off by commas, e.g., Maximum Diversified Demand, kW and Annual Load Factor, Percent. Necessary abbreviations, including months and days of the week are made without periods.

Contents of Tables

In general, contents of tables are left to the individual preparing the report. However, when a report concerns characteristics of class or appliance loads, the basic summary tables should, if possible, include: annual use, non-coincident maximum and maximum diversified demands for significant periods, load factors, coincidence factors, demand factors, customer and appliance characteristics (including saturations and connected loads) and duration of test. Monthly use and demand data may be included. Summer and winter load characteristics, when significant, should be included if monthly data are not available. Summary data may be for the total sample or for identifiable and significantly different subgroups within the sample.

Individual customer use and demand data may be included, but should be limited to basic information that is of general interest, and listed in meaningful order. Confidentiality of individual customers must be maintained.

If possible, tabular data should be complete for all test periods and for all customers. Where data are lacking, estimates may be made and so identified. In tests of short duration, energy use and demands should be for the identical test customers; bias resulting from incomplete records should be clearly stated.

Footnotes for Tables

General footnotes which apply to an entire table are designated by Note: or Notes: at the left margin below the table.

Specific footnotes are designated by a superscript numeral in a bracket immediately following and on the line with the phrase or number to be elaborated on, for example:

Number of customers tested 1/

Rated capacity per customer, kW. . . 10.85 2/

The body of the table should be separated from the footnotes by two spaces, a solid line and another space.

Preparation of Charts

Specific rules applicable to chart preparation, including computer-generated charts where applicable, are as follows:

1. Prepare charts of a size which will fit the 8 1/2 x 11 inch sheet of paper with at least 1 inch margin on all four sides including chart number and title.

2. Draw charts in black on heavy white paper. Do not draw a border around the chart.

3. Show major grid lines only. Use scales graduated in multiples of 1,

2, 5, or 10. If a scale other than arithmetic is used (e.g., logarithmic or probability), indicate all major divisions and show clearly the type of scale.

4. Plot all results substantially heavier than the grid lines.

5. Do not plot too many curves on the same chart. If possible, avoid overlapping curves. When overlapping does occur, the lines should be clearly differentiated (solid, broken, etc.).

6. Include a legend identifying the various lines and symbols either above or within the chart area. Where space or other considerations make it appropriate, identifying titles with arrows may be used.

7. Draw daily load curves as a series of straight lines from point to point, not in horizontal block form. Plot each integrated value (15-minute, half-hour, hour) at the end of the time interval according to local time. Show the plotting interval and time zone at the bottom of the chart, e.g., HALF-HOUR ENDED (EST).

8. Monthly energy use and demands may be shown as line or bar charts. Correlations may be shown as scatter diagrams or as straight-line or curvilinear relationships. Such charts may show the relationships between such variables as energy use and demand, energy use and degree-days, maximum diversified demands and number of customers or energy use and connected loads. When least squares lines are included, the equation and, if available, its coefficient of determination [1/] should be shown. Care should be taken in identifying and plotting the dependent (Y-axis) and independent (X-axis) variables.

9. Label the coordinates of a chart properly showing the variable followed by the unit in which it is expressed. Descriptive units are set off by dashes. For example:

   MONTHLY ENERGY USE PER CUSTOMERS--kWh

   TEMPERATURE--°F

   ENERGY USE--kBtu/dd/kft^3

   The X-axis identification is centered below the scale; the Y-axis label is centered sideways at the left of the scale. Identify Y-axis on both sides of the chart when plotting two simultaneous functions of X. This multiple use of the Y-axis should be avoided.

10. Include the time period of the test, kind of demand, demand interval, geographic area, and other appropriate explanatory information in the body of the chart, as part of the legend, or in the chart title.

1/ For explanation of statistical terms, see Applied Statistics in Load Research, Volume II. New York; Association of Edison Illuminating Companies, June 1965.

11. Use vertical Gothic lettering, all capitals, of sufficient size so that the smallest letter will be not less than 1/6 inch in height when reduced to the area for charts on the printed page. Make commas, periods, and decimal points in proportion. Use preprinted letters or a similar method for all lettering; do not use freehand lettering. Chart numbers and main titles should be typed.

12. Use various sizes of lettering for scale identification, legend, etc., in order of importance. Do not underline.

13. When a chart consists of more than one figure, additional care is required to assure legibility. In addition to the preceding items, the following points are important:

    (a) Select an appropriate overall title for the chart; use proper headings and coordinates to avoid unnecessary repetition.

    (b) Identify each figure on the chart either as FIG 1, FIG 2, etc., or if applicable, by a group letter and description, such as GROUP A--ANNUAL USE, 1,501-2,000 kWh. Other identifications may be used with the approval of the subcommittee chairman.

    (c) The order of figures is left to right, row by row.

    (d) When several figures are similar, a single ordinate title and a single abscissa title are used. When two or more figures are vertically or horizontally aligned as to grid lines and scale, a single scale is sufficient.

    (e) A single legend explaining the use of lines and symbols is preferred. If this is impossible, necessary indentifications should be included within the individual figures.

14. All charts should be reduced to approximately 8 1/2 x 11 inches for inclusion in the Annual Report. Mailing should be between flat cardboard sheets; avoid rolling and the use of paper clips.

ABBREVIATIONS AND SYMBOLS

In Reports of the Load Research Committee, certain rules apply to the use of abbreviations and symbols in the text, tables, and charts. Appendix A, pages 17-19, shows those commonly used in load research reports. In addition, these general rules should be followed:

1. In the text, use approved abbreviations for units of measurement with amounts expressed in numerals, e.g. 8.0 kW, $1.00, 60%, 30 ft, 75 gal, 30 min, etc.

2. Except as in No. 1 above, use abbreviations sparingly in the text.

Do not abbreviate where there is a possibility of misunderstanding. Spell out any uncommon term followed by its abbreviation in parentheses when used for the first time.

3. Use the same abbreviation for singular and plural; do not add an "s" to such abbreviations as kW, kWh, Btu, etc.

4. Avoid the use of symbols in the text; in tables and charts, use symbols only when necessary to conserve space. However, diagonals (/ for per) may be used in conjunction with common abbreviations in the text, tables, and charts, e.g., Btu/h, kWh/dd/kft^3.

5. Avoid abbreviations in main headings of charts and tables.

6. In tables, use abbreviations without periods. Note that the first letters of abbreviations in column headings are capitalized, but in line identifications may be lower case.

7. Write abbreviations such as EEI, IEEE, and AEIC without spaces and periods. Spell out names where the same abbreviation applies to more than one organization.

8. For abbreviations not listed, use as a primary authority the American National Standards Institute, Inc., Letter Symbols for Units Used in Science and Technology (ANSI Y 10.19--1969).

9. For statistical terms and symbols, see Applied Statistics in Load Research, Volume I, New York: Association of Edison Illuminating Companies, May 1964.

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APPENDIX B

STATISTICAL METHODS

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B.1 ELEMENTARY STATISTICAL CONCEPTS

Basic Terms and Ideas

This section provides a more detailed discussion of the major statistical concepts introduced in Sec. 1.3.2 of this volume. The following remarks apply to a simple random sample but demonstrate concepts relevant to all sample types.

Suppose there is a population of size N and the researcher seeks to estimate the value of a certain parameter X of that population. For example, if one attempts to estimate the height of the average 20-year-old American man, the population would be the set of 20-year-old American men and the parameter observed is the height of each such man. It is theoretically possible to survey every unit in that population, observing the value of X in each unit i, denoted X_i. Each X_i has two parts, an expected value, μ, which is the same for all i, and a stochastic error, e_i, which varies with each unit i but is expected to be zero. If e_i is expected to be zero, this does not mean e_i is always zero, only that its chances of being above or below zero are equal. When e_i is not equal to zero, X_i differs from its expected value μ by an amount e_i. Therefore, X_i is expected to be μ ; its chances of being above or below μ are equal.

Since X_i is not always equal to μ, it is useful to measure the degree of dispersal of X_i about μ; it can be wide or narrow (see Figure B.1). The population variance, σ^2, is defined as:

$$\sigma^2 = \sum_{i=1}^{N} (X_i - \mu)^2/N$$
$$= [(X_1 - \mu)^2 + (X_2 - \mu)^2 + \ldots + (X_N - \mu)^2]/N \qquad (B.1)$$

and the population standard deviation is $\sigma = \sqrt{\sigma^2}$. For a fixed μ, the larger the standard deviation, the wider the dispersal. Once again, while dispersals and hence standard deviations can vary across populations, the expected value of each error term, e_i, remains zero and therefore the expected value of X_i remains μ.

Unless the population is small, one would find a complete survey to ascertain μ and σ^2 very expensive. Consequently, researchers survey a subset of the population and examine sample statistics to assess corresponding population parameters. Two statistics avail themselves to the researcher who seeks to identify population parameters with a sample. Upon choosing a sample of size n (n < N), one may define the sample mean, $\bar{X}$, (see Table B.1) as:

$$\bar{X} = \sum_{i=1}^{n} X_1/n = (X_1 + X_2 + \ldots + X_n)/n$$

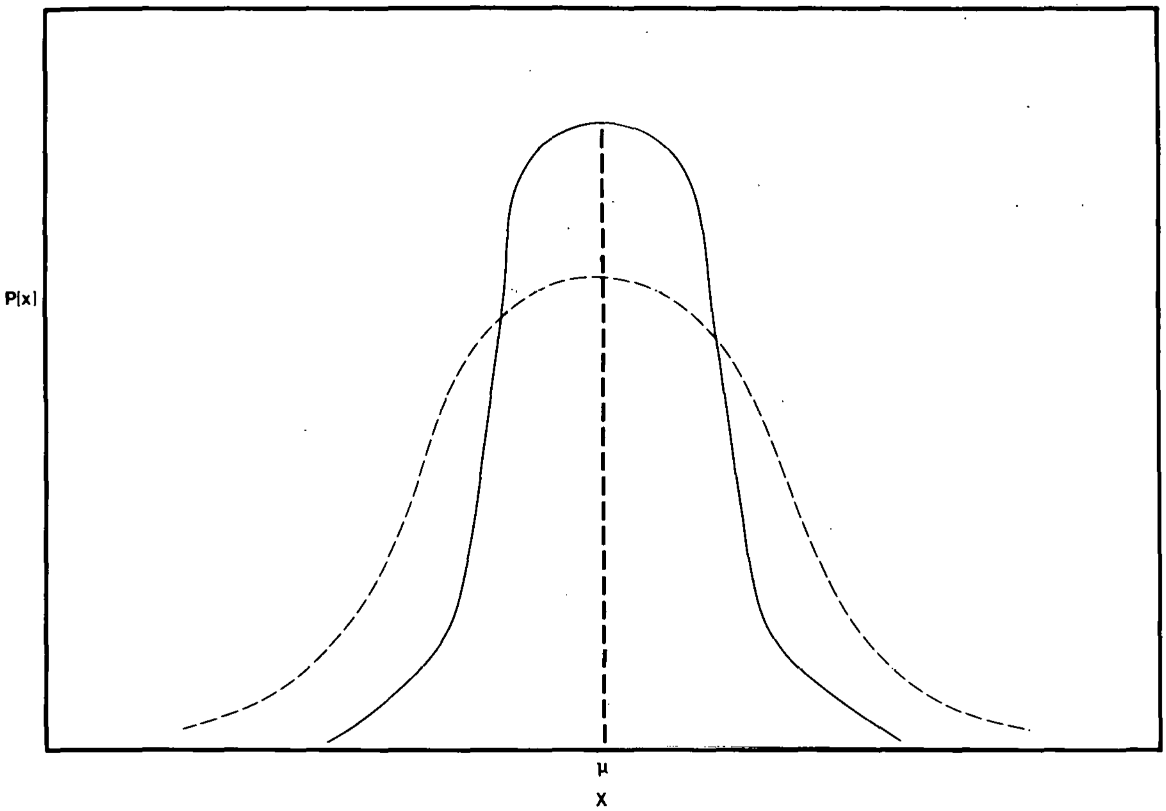

Fig. B.1 Wide (dashed line) and Narrow (solid line) Dispersal of a Variable

The expected value of the mean $\bar{X}$ is the expected value of the population mean, μ. One may also estimate the sample variance, s^2 (see Table B.1) as:

$$s^2 = \sum_{i=1}^{n} (X_i - \bar{X})^2/(n - 1)$$

$$= [(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \ldots + (X_n - \bar{X})^2]/(n - 1)$$

The expected value of the sample variance, s^2, is the population variance, σ^2. Furthermore, one may define the sample deviation as $s = \sqrt{s^2}$.

As with X_i, $\bar{X}$ will not always equal μ; it is only expected to equal μ. It can in fact be above or below μ, but has equal chances of being either. $\bar{X}$ then is also dispersed around μ, its expected value. It can be shown that the variance of $\bar{X}$, $s_{\bar{X}}^2$, is:

$$s_{\bar{X}}^2 = s^2/n \tag{B.2}$$

and its standard deviation $s_{\bar{X}} = \sqrt{s_{\bar{X}}^2}$. Therefore, the standard deviation of a sample mean decreases as the sample size, n, increases.

Table B.1 Calculation of Sample Mean and Variance

Customer	Demand (X_i)	$X_i - \bar{X}$	$(X_i - \bar{X})^2$
1	50	-50	2,500
2	60	-40	1,600
3	110	+10	100
4	140	+40	1,600
5	90	-10	100
6	150	+50	2,500
7	120	+20	400
8	160	+60	3,600
9	40	-60	3,600
10	80	-20	400
ΣX_i =	1,000		16,400
$\bar{X}$ =	100		

$$s^2 = 16{,}400/9 = 1{,}822$$

$$s = 42.68$$

Since the standard deviation of the mean measures a calculated statistic's dispersal around its expected value and since increasing the sample size decreases this standard deviation (Eq. B.2), larger samples produce more reliable, less dispersed statistics, all else being equal. Regardless of the distribution of e_i around zero and X_i around μ, the Central Limit Theorem states that for large samples, $\bar{X}$ is dispersed around μ with a normal distribution, the bell-shaped curve depicted in Figure B.2. This is useful since this distribution has been well-researched and readily avails itself to confidence testing.

The properties of the normal distribution assure the researcher that if $\bar{X}$ is normally distributed around μ with sample variance $s^2_{\bar{x}}$, there is a 68% chance that $\bar{X}$ will lie between $\bar{X} - s_{\bar{x}}$ and $\bar{X} + s_{\bar{x}}$. There is a 95% chance that $\bar{X}$ will lie between $\bar{X} - 2s_{\bar{x}}$ and $\bar{X} + 2s_{\bar{x}}$ and more than a 99% chance for $\bar{X}$ to lie between $\bar{X} - 3s_{\bar{x}}$ and $\bar{X} + 3s_{\bar{x}}$. One of these percentages, 68%, 95%, and 99%, will be the confidence of the estimation. The wider the bandwidth, the more confident one may be that it contains μ. Other degrees of certainty and the procedure for reading a normal distribution table are discussed in Sec. B.2 of this appendix.

Since $s^2_{\bar{x}}$ is inversely proportional to the sample size, n, the variance of the sample mean decreases as n rises. Though σ^2 and s^2 can be considered constant, $s^2_{\bar{x}}$ can be reduced as long as n can be increased. Therefore, the 68%, 95%, and 99% bandwidths (as well as any other) can be reduced in length. One can obtain more secure and reliable estimates of μ by increasing n and reducing $s^2_{\bar{x}}$ and all confidence bandwidths.

The half-length of the bandwidth is often depicted as a percentage of the expected value, estimated by the sample mean. A ±5% bandwidth with

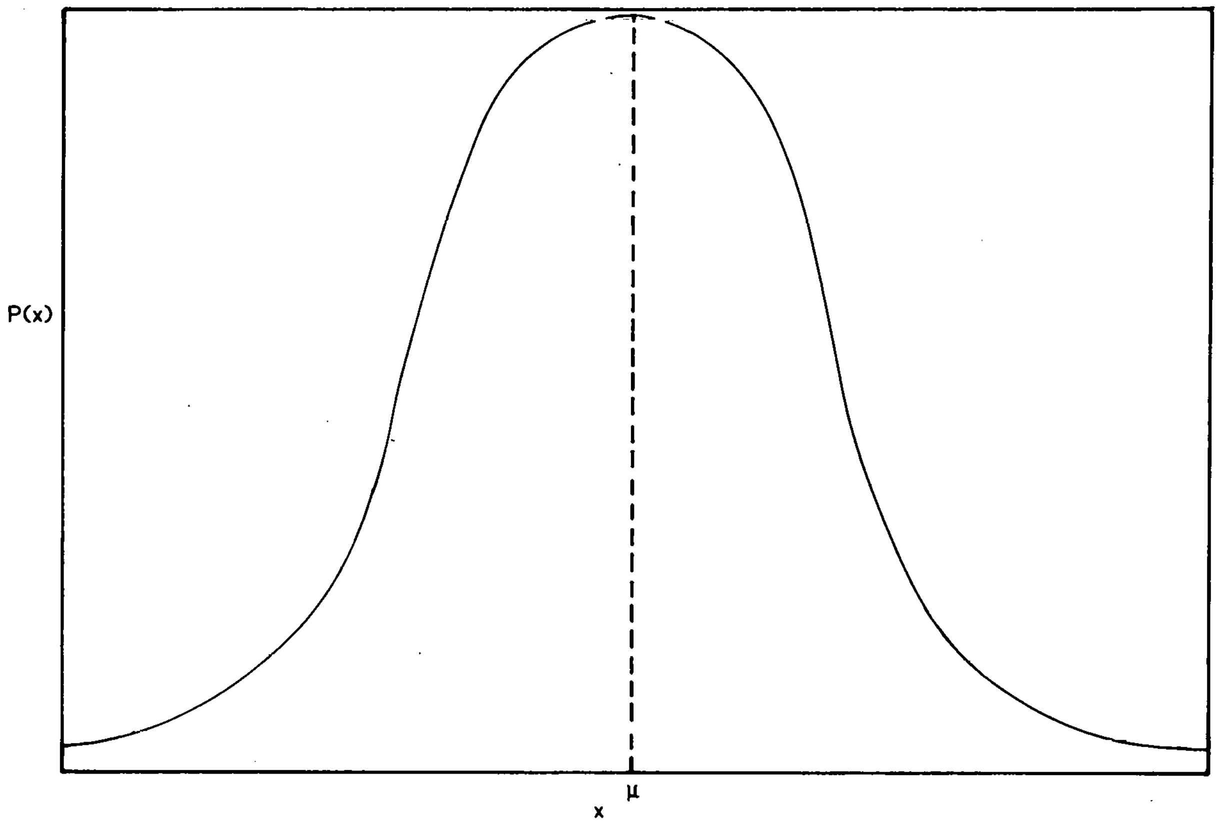

Fig. B.2 The Normal Distribution

90% confidence implies that one may be 90% certain that the sample mean lies within 5% of its expected value. To obtain, for example, a ±5% bandwidth with 90% certainty, one reads from the normal distribution table that the standard normal deviate (Z) corresponding to 90% confidence is 1.645 (see Sec. B.2 of this appendix for an explanation of the normal distribution table and the Z statistic). Therefore, $\bar{X} \pm 1.645$ will contain μ with 90% certainty. The half-length of the bandwidth, $1.645s_{\bar{X}}$ in this case, is expressed as a fraction, q, of $\bar{X}$:

$$q = 1.645s_{\bar{X}}/\bar{X}$$

To convert this fraction to a percentage of $\bar{X}$, multiply by 100.

The coefficient of variation is $s_{\bar{X}}/\bar{X}$, or V. As $\bar{X}$ increases, $s_{\bar{X}}$, q, and V are reduced. By increasing n enough, one may reduce q to 5% of $\bar{X}$ or, equivalently, reduce V to 3% (5/1.645) of $\bar{X}$. This value of n is then the sample size with which one can estimate a ±5% bandwidth around μ with 90% confidence. The confidence is 90% and the reliability is 5%.

For samples with less than 30 observations, the normal distribution table is not adequate for representing confidence intervals. For these samples, the Student t distribution is more appropriate (see Sec. B.3 of this appendix).

This discussion has asserted that a company can obtain any desired degree of confidence and reliability in its sample estimates. This is true so long as the sample size n can be increased. Very often, power companies, especially small ones, do not have the necessary capital to buy more meters and expand the sample size. For these companies, the size of the sample often cannot be expanded to permit the desired degrees of confidence and reliability. Accordingly, one defines sample variance as before:

$$s_{\bar{x}}^2 = s^2/n$$

and defines the coefficient of variation as $V = s_{\bar{x}}/\bar{X}$. For a prescribed confidence C, one may then obtain the corresponding normal statistic Z (or Student t statistic) from the normal distribution table; for example, Z(90) = 1.645. Then reliability, r, is obtained from Z (or t) and V:

$$r = Z(c)V$$

If this degree of reliability r is unacceptable, the company should either buy more meters, pool efforts with another company, or not conduct the survey.

Alternatively, a utility may calculate the sample variance, $s_{\bar{x}}^2$, and the coefficient of variation, V; prescribe the reliability, r; and then estimate the resulting Z (or t): Z = r/V. The corresponding confidence level of Z (or t) is obtained from the normal (or Student t) distribution table. If this level of confidence is unacceptable, the utility should buy more meters, pool efforts, or not conduct the experiment.

Equation B.2 provides an estimate of the variance of the sample mean. Theoretically, this is valid only when the sample size is small relative to the population size. When this is not the case, it is necessary to adjust this variance with the finite population correction. The adjusted variance of the sample mean is then written as:

$$s_{\bar{x}}^2 = (1 - f)s^2/n$$

where:

s^2 = variance of individual customer,

n = sample size,

f = finite population correction = n/N (becomes important when n/N is large), and

N = population size.

Stratification and Reliability

By stratifying a sample, a statistician might be able to reduce the overall variance of the sample mean. In a simple random sample, the variance of a sample customer's demand is expressed as:

$$s^2 = \sum_{i=1}^{n} (X_i - \bar{X})^2/(n - 1)$$

where:

$\bar{X}$ = sample mean of parameter X,

X_i = value of X for customer i, and

n = sample size.

The variance of the sample mean, $s^2_{\bar{x}}$, is then expressed as:

$$s^2_{\bar{x}} = s^2/n \tag{B.3}$$

If the finite population correction is warranted:

$$s^2_{\bar{x}} = (1 - n/N)s^2/n$$

Since s^2 is expected to be constant, one can reduce $s^2_{\bar{x}}$ by increasing the sample size, n. As long as n can be increased, $s^2_{\bar{x}}$ can be reduced and reliability and confidence can be enhanced.

If the sample is stratified, it is possible to estimate each stratum member's variance, s^2_j, around the stratum's mean:

$$s^2_j = \sum_{i=1}^{n_j} (X_{ij} - \bar{X}_j)^2/(n_j - 1)$$

where:

$\bar{X}_j$ = sample mean of parameter X for stratum j,

X_{ij} = value of X for customer i in stratum j, and

n_j = size of sample stratum j.

The variance of the sample stratum mean $\bar{X}_j$ is then:

$$s^2_{\bar{x}_j} = s^2_j/n_j$$

If the finite population correction is warranted:

$$s^2_{\bar{x}_j} = (1 - n_j/N_j)s^2_j/n_j$$

where N_j = size of population stratum j. To estimate the variance $s^2_{\bar{x}}$ of the overall sample mean for a stratified random sample, one must use:

$$s^2_{\bar{x}} = \sum_{j}^{J} N^2_j s^2_{\bar{x}_j}/N^2 \tag{B.4}$$

where N = population size. One then may compare this with the variance of the overall sample mean for a simple random sample in Eq. B.3. Usually, but not always, the resulting variance in Eq. B.4 is smaller. Accordingly, stratification usually reduces the overall variance of the sample mean.

B.2 THE NORMAL DISTRIBUTION

Statistical Theory

A random variable X is normally distributed around μ if its frequency can be depicted by the bell-shaped curve displayed in Figure B.2. The value of X ranges between negative and positive infinity $(-\infty,\infty)$, is symmetric around μ, and peaks at μ. Since frequencies correspond to probabilities, the area beneath the normal curve, which is the sum of all probabilities, must equal unity.

The probability that $X \leq a$ is represented graphically by the area A beneath the curve to the left of a (see Figure B.3). The probability that $X \geq b$ is represented graphically by the area B beneath the curve to the right of b (Figure B.3); this figure also displays the probability that $a \leq X \leq b$. One may transform any of the above statements to a strict inequality ($<$, $>$) with no loss of validity.

When a normally distributed variable X has a mean $\mu = 0$ and a variance $\sigma^2 = 1$, it is said to be a standard normal variable. Any variable X can be transformed into a standard normal variable Z as follows:

$$Z = (X - \mu)/\sigma$$

This distribution is useful since statisticians have tabulated the frequency of the standard normal variable Z, from which one may estimate the probabilities that $X \leq a$, $X \geq b$ and $a \leq X \leq b$:

$$P(X \leq a) = P[Z \leq (a - \mu)/\sigma]$$

$$P(X \geq b) = P[Z \geq (b - \mu)/\sigma]$$

$$P(a \leq X \leq b) = P[(a - \mu)/\sigma \leq Z \leq (b - \mu)/\sigma]$$

As before, any statement can be transformed into a strict inequality with no loss of validity.

Application of the Standard Normal Table

Standard normal tables display various levels of Z* and the corresponding probability that a standard normal variable Z is less than (or equal to) Z*. Accordingly, probabilities corresponding to each level a and each area A in Figure B.3 are immediately available from a standard normal table. To obtain the probabilities that a standard normal variable is greater than (or equal to) Z*, the following equation is used:

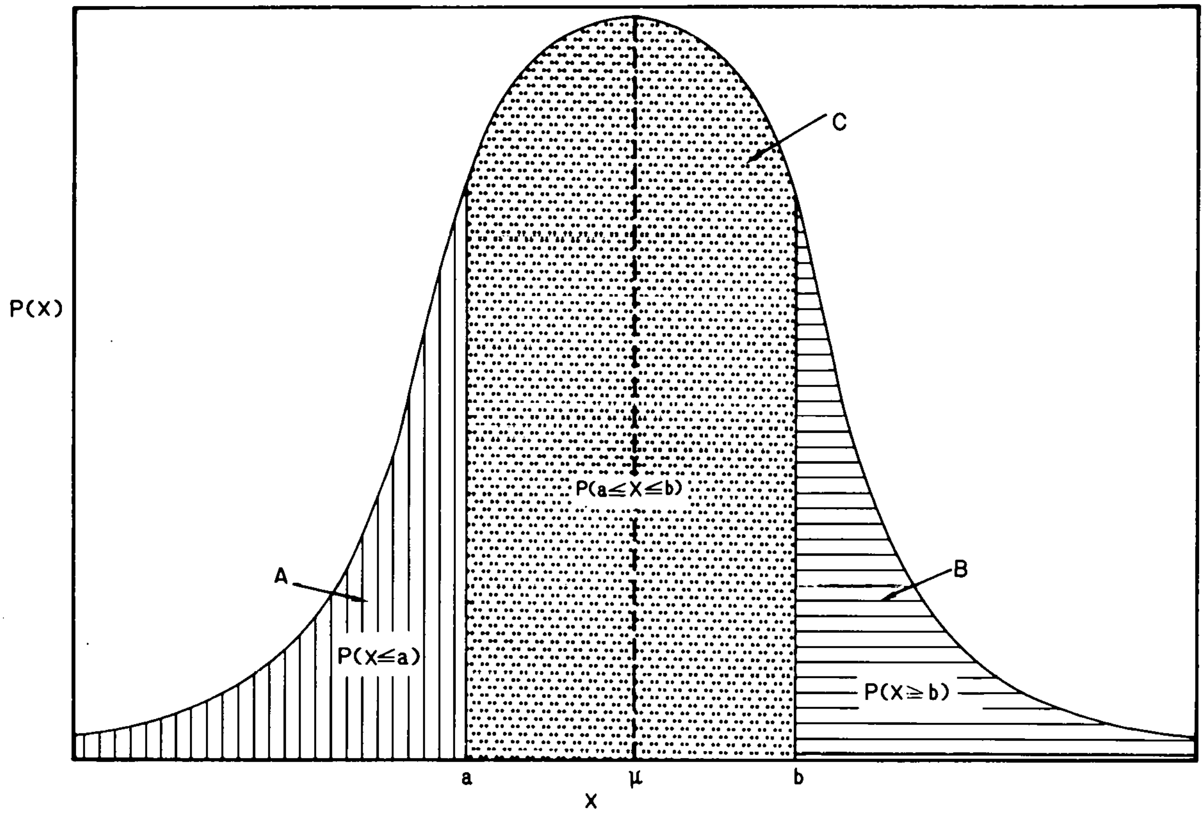

Fig. B.3 Probabilities Determined Using a Standard Normal Distribution

$$P(Z \geq Z^*) = 1 - P(Z \leq Z^*)$$

Thus, it is possible to estimate probabilities corresponding to each level b and each area B in Figure B.3 by subtracting from unity the parameters in the standard normal table. Finally, the probabilities that $Z^* \leq Z \leq Z^{**}$ can be estimated using:

$$P(Z^* \leq Z \leq Z^{**}) = P(Z \leq Z^{**}) - P(Z \leq Z^*)$$

Consequently, it is possible to estimate probabilities corresponding to each area C in Figure B.3.

Reading the Standard Normal Table

The standard normal table (Table B.2) displays down the left-hand side each Z and in the grid the probability that a standard normal variable is less than Z. The ten numbers across the top indicate the next decimal place for the left-hand Z. For example, the probability that a standard normal variable is less than -3.0 is 0.0013, is less than -3.1 is 0.0010, and is less than -3.8 is 0.0001.

Table B.2 Example of a Normal Distribution Table[a]

Z	0	1	2	3	4	5	6	7	8	9
-3.0	.0013	.0010	.0007	.0005	.0003	.0002	.0002	.0001	.0001	.0000
-2.9	.0019	.0018	.0017	.0017	.0016	.0016	.0015	.0015	.0014	.0014
-2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
-2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
-2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
-2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
-2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
-2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
-2.2	.0139	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110
-2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
-2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
-1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0238	.0233
-1.8	.0359	.0352	.0344	.0336	.0329	.0322	.0314	.0307	.0300	.0294
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

[a]This excerpt from a larger table gives probabilities only on one side of the curve shown in Figure B.3.

B.3 THE STUDENT t DISTRIBUTION

Statistical Theory

A random variable X has a Student t distribution if it can be represented as the ratio of a standard normal variable Z (Sec. B.2 of this appendix) to a square root of a chi-square distributed variable Y divided by Y's degrees of freedom.* That is:

$$X = Z/\sqrt{Y/n}$$

where Z is normally distributed with mean 0 and variance 1, and Y is chi-square distributed with n degrees of freedom.

The value of X ranges between negative and positive infinity $(-\infty,\infty)$, is symmetric around 0, and peaks at 0. Its frequency can be depicted by a bell-shaped curve; the shape of this curve is extremely similar, but not identical, to that of the standard normal curve. The frequency distribution and therefore the curve change as n increases; the limiting case (as n approaches infinity) of the Student t distribution is the standard normal distribution. When n exceeds 30, there is little difference between the Student t and the standard normal distribution. Since frequencies correspond to probabilities, the area beneath the Student t curve, which is the sum of all probabilities, must equal unity.

*See Morrison, D.S., Multivariate Statistical Methods, McGraw Hill Book Co., New York City, p. 10 (1976).

The probability that $X \leq a$ is represented by the area beneath the Student t curve (which is similar in shape to the curve in Figure B.3) to the left of a while the probability that $X \geq b$ is represented by the area beneath the curve to the right of b. Finally, the probability that $a \leq X \leq b$ is represented by the area beneath the curve between a and b. One may transform any of the above statements to a strict inequality (<, >) with no loss of validity.

Application of the Student t Table

Student t tables display various levels of t* and the corresponding probability that a Student-t-distributed variable t is less than (or equal to) t*: $P(t \leq t^*)$. Accordingly, probabilities corresponding to each value of a are immediately available from a Student t table. To obtain the probabilities that a Student t variable is greater than (or equal to) t*:

$$P(t \geq t^*) = 1 - P(t \leq t^*)$$

Thus, it is possible to estimate probabilities corresponding to each value of b by subtracting from unity the parameters in the Student t table. Finally, the probabilities that $t^* \leq t \leq t^{**}$ can be estimated:

$$P(t^* \leq t \leq t^{**}) = P(t \leq t^{**}) - P(t \leq t^*)$$

Reading the Student t Table

The Student t distribution table (Table B.3) displays down the left-hand side the degrees of freedom n and across the top the t statistics corresponding to various probabilities p, which are written in the subscripts. The statistics in the grid indicate for each n and p those numbers t* where:

$$P(t \leq t^*) = p$$

when t has a Student t distribution. For example, for 15 degrees of freedom, the probability that a Student-t-distributed variable t is less than 1.07 is 0.85; the probability that t is less than 1.75 is 0.95.

B.4 FORWARD LOOKING STRATIFICATION AND SAMPLE SIZING

Load researchers cannot choose either sample size or strata allocations until certain variances of customer demand are estimated. Since these variances cannot actually be calculated until the experiment is completed, one must obtain rough estimates of their magnitude. Most researchers use rough estimates of present variances, but more-sophisticated researchers may wish to estimate likely future variances. In this way, the sample may be designed for the period when the research is to be used. Three mathematical procedures can be used for forward stratification.

A simple way of estimating future customer variances from present information is to assume proportionality between customer demand variance (or standard deviation) and demand (or usage) magnitude. By identifying the

Table B.3 The Student t Distribution[a]

Degrees of Freedom	$t_{.55}$	$t_{.60}$	$t_{.65}$	$t_{.70}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.9995}$
1	.158	.325	.510	.727	1.00	1.38	1.96	3.08	6.31	12.7	31.8	63.7	637
2	.142	.289	.445	.617	.816	1.06	1.39	1.89	2.92	4.30	6.96	9.92	31.6
3	.137	.277	.424	.584	.765	.978	1.25	1.64	2.35	3.18	4.54	5.84	12.9
4	.134	.271	.414	.569	.741	.941	1.19	1.53	2.13	2.78	3.75	4.60	8.61
5	.132	.267	.408	.559	.727	.920	1.16	1.48	2.01	2.57	3.36	4.03	6.86
6	.131	.265	.404	.553	.718	.906	1.13	1.44	1.94	2.45	3.14	3.71	5.96
7	.130	.263	.402	.549	.711	.896	1.12	1.42	1.90	2.36	3.00	3.50	5.40
8	.130	.262	.399	.546	.706	.889	1.11	1.40	1.86	2.31	2.90	3.36	5.04
9	.129	.261	.398	.543	.703	.883	1.10	1.38	1.83	2.26	2.82	3.25	4.78
10	.129	.260	.397	.542	.700	.879	1.09	1.37	1.81	2.23	2.76	3.17	4.59
11	.129	.260	.396	.540	.697	.876	1.09	1.36	1.80	2.20	2.72	3.11	4.44
12	.128	.259	.395	.539	.695	.873	1.08	1.36	1.78	2.18	2.68	3.06	4.32
13	.128	.259	.394	.538	.694	.870	1.08	1.35	1.77	2.16	2.65	3.01	4.22
14	.128	.258	.393	.537	.692	.868	1.08	1.34	1.76	2.14	2.62	2.98	4.14
15	.128	.258	.393	.536	.691	.866	1.07	1.34	1.75	2.13	2.60	2.95	4.07
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
	.126	.253	.385	.524	.674	.842	1.04	1.28	1.64	1.96	2.33	2.58	3.29

[a]This excerpt from a larger table gives probabilities only on one side of the curve shown in Figure B.3.

probable growth of demand or usage, one may identify the likely change in the customer's variance. For example, suppose customer variance in time t, $\hat{s}_t^2$, is proportional to customer usage X_t in that period:

$$\hat{s}_t^2 = KX_t$$

where K is a proportionality constant. Furthermore, if X_t is expected to increase (or decrease) in some later period T, then:

$$\hat{s}_T^2 = KX_T$$

One may estimate $\hat{s}_T^2$ as follows:

$$\hat{s}_T^2 = \hat{s}_t^2(X_T/X_t)$$

Alternatively, the customer standard deviation $\hat{s}_t$ can be assumed to be proportional to X_t:

$$\hat{s}_t = KX_t$$

A more sophisticated procedure entails estimating a linear regression between the stratifying variable Y and independent variable(s) X where X(s) affects Y and is forecasted (Sec. 1.8.3 of this volume describes linear regression and suggests more-technical sources for the interested reader). Basically, linear regresion fits a linear equation that best describes the relationship between Y and X(s) in any time period t:

$$Y_t = a + bX_t \tag{B.5}$$

where a and b are constants. This relationship can be estimated from available data. If X is forecasted to increase (or decrease) to X_T at a later time T, one may estimate the variance of Y at time T as:

$$\hat{s}_T^2 = \hat{s}_t^2 \, [1 + (1/n) + (X_T - X_t)^2/Q] \tag{B.6}$$

where:

$\hat{s}_t^2$ = estimated variance of Y_t at time t,

n = number of observations used to estimate a and b in Eq. B.5,

$$Q = \sum_{i=1}^{n} (X_i - \bar{X})^2,$$

$\bar{X}$ = historical mean of X_i, and

X_i = observation of X_i.

A further degree of sophistication is possible. Equation B.6 is useful for estimating the future variance $\hat{s}_T^2$ given that the independent variable X will approach X_T. This is rarely known for certain. More likely, X will be forecast to rise (or fall) to X_T with its own variance $\hat{s}_x^2$. To estimate the variance of Y in a forecast period T, one may add an adjustment A to the estimated $\hat{s}_T^2$ in Eq. B.6. This allows for the fact that neither a, b, nor X_T are known with certainty:

$$A = \hat{s}_x^2 \left[b^2 + \hat{s}_t^2 X_{T+1}^2 / Q \right]$$

Upon estimating future customer demand variances, the researcher may design the sample as before. The forecasted variances $\hat{s}_T^2$ are used to design the strata, allocate the sample customers, and estimate sample size.

B.5 TESTS ON CORRELATION COEFFICIENTS

Two variables, X and Y, often are related to each other. If X and Y increase and decrease together, they are positively correlated (see Figure B.4). If X increases while Y decreases and vice versa, they are negatively correlated (see Figure B.5). The correlation coefficient, ρ, measures the extent of their correspondence. If there are N observations on X and Y in the population, the population covariance σ_{xy} is defined as:

$$\sigma_{xy} = \sum_{i=1}^{N} (X_i - \mu_x)(Y_i - \mu_y)/N$$

where:

μ_x = population mean of X, and

μ_y = population mean of Y.

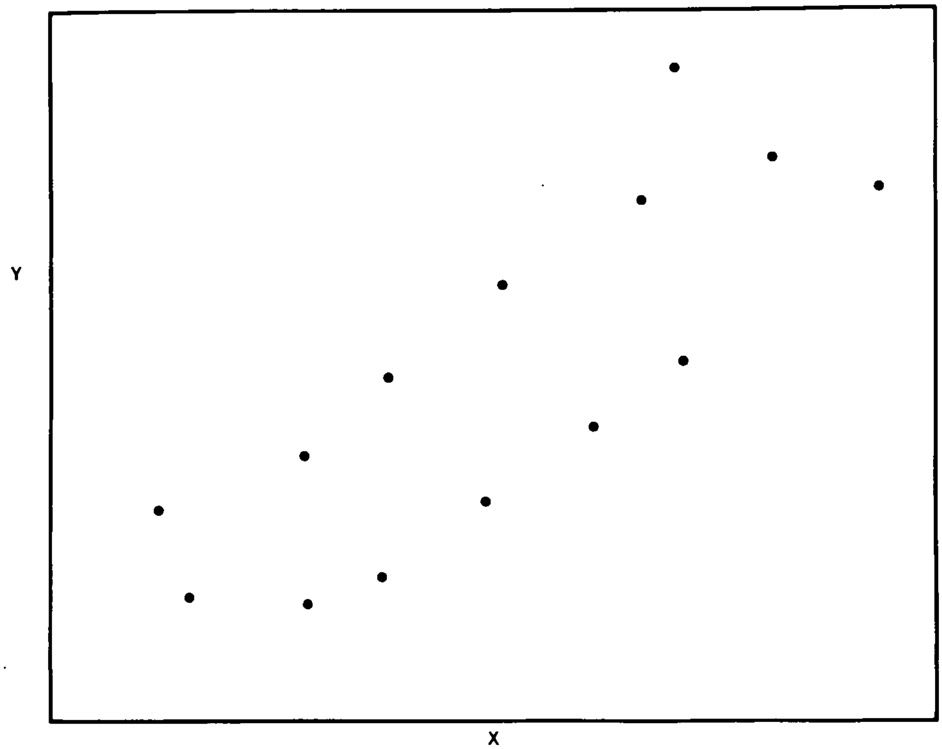

Fig. B.4 Positive Correlation between Y and X

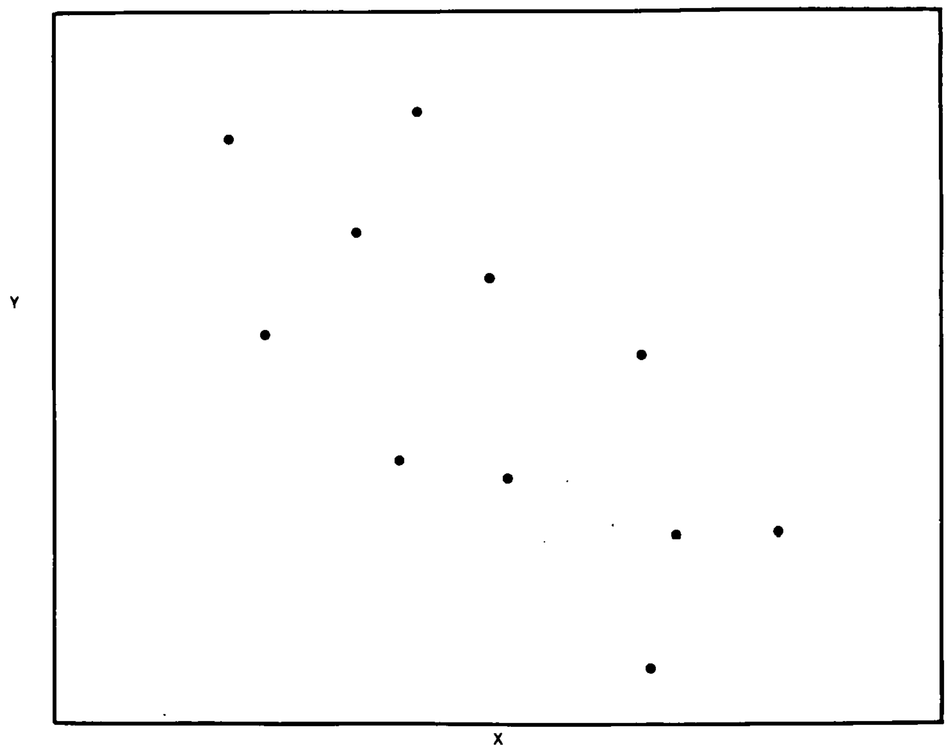

Fig. B.5 Negative Correlation between Y and X

The population correlation coefficient ρ is defined as:

$$\rho = \sigma_{xy}/\sigma_x\sigma_y$$

where:

σ_x = population standard deviation of X, and

σ_y = population standard deviation of Y.

It can be shown that $-1 \leq \rho \leq 1$.

If a sample is surveyed, the sample covariance s_{xy} is defined as (see Table B.4):

$$s_{xy} = \sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y})/(n - 1)$$

where:

n = sample size,

$\bar{X}$ = sample mean of X, and

$\bar{Y}$ = sample mean of Y.

The sample correlation coefficient r is defined as (see Table B.4):

$$r = s_{xy}/s_x s_y$$

where:

s_x = sample standard deviation of X, and

s_y = sample standard deviation of Y.

Sample correlation coefficients can be tested to evaluate whether they are equal to 0, some other constant ($-1 \leq k \leq 1$), or another correlation coefficient.

If X and Y are normally distributed, one may test whether $r = 0$ with a t statistic:

$$t = r\sqrt{(n - 2)/(1 - r^2)}$$

where t is distributed with a Student t distribution (see Sec. B.3 of this appendix) with $n - 2$ degrees of freedom.

If X and Y are normally distributed, one may test whether $r = k$ ($k \neq 0$) with a Z statistic:

$$Z = 0.5 \log[(1 + r)/(1 - r)]\sqrt{n - 3}$$

where Z is normally distributed (see Sec. B.2 of this appendix). This test should not be used for small values of n.

Table B.4 Calculation of Sample Covariance and Correlation Coefficient

Customer Group 1	Demand (X_i)	Customer Group 2	Demand (Y_i)	$(X_i - \bar{X})(Y_i - \bar{Y})$
1	50	11	60	2,000
2	60	12	80	800
3	110	13	90	-100
4	140	14	150	2,000
5	90	15	110	-100
6	150	16	140	2,000
7	120	17	160	1,200
8	160	18	120	1,200
9	40	19	80	1,200
10	80	20	40	1,200
	ΣX_i = 1,000		ΣY_i = 1,000	11,400
	$\bar{X}$ = 100		$\bar{Y}$ = 100	
	s_x^2 = 1,822		s_y^2 = 1,822	
	s_x = 42.7		s_y = 42.7	s_{xy} = 1,267

$$r = 1{,}267/(42.7^2) = 0.695$$

If two independent samples of sizes n_1 and n_2 are drawn from bivariate normal populations, one may test whether $r_1 = r_2$ with a Z statistic:

$$Z = (q_1 - q_2)/\sqrt{1/(n_1 - 3) + 1/(n_2 - 3)}$$

where:

$$q_1 = \log\,[(1 + r_1)/(1 - r_1)]$$

$$q_2 = \log\,[(1 + r_2)/(1 - r_2)]$$

In this case, Z is normally distributed. This test should not be used with small values of n_1 or n_2.

If X, Y, and Z (or more variables) are jointly distributed, one may calculate correlation coefficients for any two in the same manner as above. All tests remain the same. It is also possible to calculate partial correlation coefficients between any two variables that purge the relationships of any other variable's influence. These are rarely used in load research and are beyond the scope of this manual. In addition, it is possible to test simultaneously hypotheses regarding several correlation coefficients such as $r_{xy} = 0$ and $r_{xz} = 0$. This requires rather sophisticated mathematical knowledge and is beyond the scope of this manual.

For a good technical discussion of these complex correlation tests, the reader is referred to Morrison, D.F., Multivariate Statistical Methods, McGraw-Hill Book Co., New York City, Chapter 3, pp. 102-120 (1976).

B.6 NEYMAN OPTIMAL ALLOCATION

When variances of customer loads are known before the sample is designed, the Neyman optimal allocation procedure may be used to stratify the sample. It can produce more efficient overall sample variances than proportional allocation does if variances of customer demands differ across strata.

In a proportional sample allocation, meters are allocated across J sample strata in proportion to each stratum's share in the population:

$$n_i/n = N_i/N$$

where:

n_i = number of meters in sample stratum i,

n = total number of meters in sample,

N_i = number of customers in population stratum i, and

N = total number of customers in population.

If the sample is to be stratified on the basis of one continuous variable, Neyman procedures allocate to each stratum i as follows:

$$n_i/n = N_i s_i / \sum_{i=1}^{J} N_i s_i$$

where s_i = variances of customer loads in stratum i. If the sample is to be stratified on the basis of more than one continuous variable, it is still possible to use more-sophisticated Neyman procedures, but these will not be described here.

As an example, suppose that in a two-stratum sample, stratum 1 has 200,000 customers and stratum 2 has 100,000 customers. A proportional allocation scheme would allocate the meters to the two strata with a two to one ratio in favor of stratum 1. However, suppose that the stratum 1 group demand at hour i has a standard deviation of 100 while the corresponding stratum 2 demand has a larger standard deviation of 200. Then the allocation to stratum 1 is expressed as:

$$\begin{aligned} n_1/n &= N_1 s_1/(N_1 s_1 + N_2 s_2) \\ &= 200{,}000 \cdot 100/(200{,}000 \cdot 100 + 100{,}000 \cdot 400) \\ &= 1/3 \end{aligned}$$

Furthermore, $n_2/n = 2/3$. A Neyman allocation scheme would allocate the meters to the two strata with a two to one ratio in favor of stratum 2.

B.7 THE DALENIUS-HODGES TECHNIQUE

In an optimally allocated stratified random sample, one may use the Dalenius-Hodges technique to choose strata breakpoints. This procedure works as follows.

Upon defining the stratifying variable, the researcher must divide the population into several short segments. Each segment i has a frequency f_i and an interval length u_i. Q_i may be calculated as:

$$Q_i = \sqrt{u_i f_i}$$

Upon estimating each segment's Q_i, one estimates R_i for each segment i:

$$R_i = \sum_{j \leq k} Q_j = Q_1 + Q_2 + \ldots + Q_i$$

This R_i is called cum $\sqrt{uf}$. Next, from R_I (where I represents the last segment) calculate the interval length K:

$$K = R_I / J$$

where J = desired number of sample strata. Then find those segments where:

$$R_1 = K$$
$$R_2 = 2K$$
$$R_3 = 3K$$
$$\vdots$$
$$R_{I-1} = (I - 1)K$$
$$R_I = IK$$

Survey strata should begin and end at these values of R. The strata breakpoints should be the values of the stratifying variable Y that correspond to the R values.

The following example demonstrates this procedure. Suppose the stratifying variable Y ranges from 0 to 100. Table B.5 displays the segments and their respective frequencies and intervals. To divide this sample into three strata, $R_I = 84.82$ is divided by $J = 3$ to obtain $K = 28.27$. The segment containing $R_1 = 28.27$ is 20-25, and the 40-50 segment contains $R_2 = 2 \cdot 28.27 = 56.54$. Therefore, strata breakpoints should be chosen from these two segments: 20-25 and 40-50.

After defining the breakpoints, the researcher must allocate the available meters to each stratum with the Neyman allocation procedure (see Sec. B.6 of this appendix). The number of meters to be used in the total survey may or may not be optimal. (Sec. 1.3.5 of this volume also discusses the procedure for optimally sizing a stratified sample.) Upon allocating the meters to the strata, the researcher must calculate the overall sample variance and standard deviation $s_{\bar{x}}$ (see Sec. B.1 in this appendix) and the coefficient of variation V.

At this stage, the researcher should then add an additional stratum, recalculate the Dalenius-Hodges breakdown, reallocate the meters, and estimate the new coefficient of variation. If it is sizably less than the old one, the additional stratum should be incorporated. This procedure should continue with the addition of yet another stratum, etc. Upon adding the additional

Table B.5 Example of Dalenius-Hodges Procedure

Stratifying Variable (Y)	Frequency f_i	u_i	Interval Length $Q_i = \sqrt{f_i u_i}$	$R_i = \text{cum}\sqrt{f_i u_i}$
0-10	9	10	9.49	9.49
10-15	7	5	5.92	15.41
15-20	8	5	6.32	21.73
20-25	10	5	7.07	28.80
25-30	13	5	8.06	36.86
30-35	9	5	6.71	43.57
35-40	8	5	6.32	49.89
40-50	9	10	9.49	59.38
50-60	7	10	8.37	67.75
60-80	5	10	7.07	74.82
80-100	5	20	10.00	84.82
	90	90		

stratum, one must be careful to re-evaluate the optimal sample size only if it is possible to obtain the additional meters; otherwise the researcher should constrain the total number of meters to be no more than what is in fact available. Generally, statisticians have found little justification for using more than six strata.

B.8 OPTIMAL SAMPLE SIZING IN STRATIFIED RANDOM SAMPLES

Optimal sample sizing in stratified random sampling is related to the desired levels of reliability and confidence, the standard deviation of the sample mean, and the allocation procedure. The formulas to calculate optimal size can also incorporate finite population corrections.

For any allocation scheme, define:

$W_j = N_j/N$

$w_j = n_j/n$

where:

N_j = size of stratum j in population,

N = total size of population,

n_j = size of stratum j in sample, and

n = total size of sample.

The optimal sample size, n_0, is given (without finite population correction) as:

$$n_0 = (1/s_{\bar{x}}^2) \sum_{j=1}^{J} W_j^2 s_j^2 / w_j$$

where:

$s_{\bar{x}}^2$ = variance of average sample mean (as calculated in Sec. B.1 of this appendix), and

s_j^2 = variance of customer in sample j.

With a finite population correction, the optimal size, n, is related to n_0:

$$n = n_0 \div [1 + \sum_{j=1}^{J} W_j s_j^2 / N s_{\bar{x}}^2]$$

The second term in the denominator is the finite population correction.

These formulas can be simplified when the allocation schemes are proportioned or optimal. In proportional allocation, $w_j = n_j/n = N_j/N = W_j$. The formula for n_0 can be simplified to:

$$n_0 = \sum_{j=1}^{J} W_j s_j^2 / s_{\bar{x}}^2$$

With a finite population correction:

$$n = n_0/(1 + n_0/N)$$

The second term in the denominator is the finite population correction.

In the Neyman optimal allocation:

$$w_j = n_j/n = N_j s_j \div \sum_{i=1}^{J} N_i s_i$$

The formula for n_0 can be simplified to:

$$n_0 = (1/s_{\bar{x}}^2)\left[\sum_{j=1}^{J} W_j s_j\right]^2$$

With a finite population correction:

$$n = \left[\sum_{j=1}^{J} W_j s_j\right]^2 \div \left[s_{\bar{x}}^2 + \sum_{j=1}^{J} W_j s_j^2 / N\right]$$

The term $s_{\bar{x}}^2$ often is specified as a function of sample mean, reliability, and confidence. The coefficient of variation $\bar{V}$ is expressed as:

$$V = s_{\bar{x}}/\bar{X}$$

where:

$s_{\bar{x}}$ = standard deviation of average sample mean, and

$\bar{X}$ = sample mean.

The reliability for r is then:

$$r = ZV$$

where Z = confidence level. Accordingly, $s_{\bar{x}}$ and $s_{\bar{x}}^2$ are expressed as:

$$s_{\bar{x}} = \bar{X}V = \bar{X}r/Z$$
$$s_{\bar{x}}^2 = \bar{X}^2r^2/Z^2$$

As an example of these procedures, consider the following allocations:

$s_1 = 400$ $\quad$ $s_2 = 100$

$N_1 = 1000$ $\quad$ $N_2 = 2000$

$W_1 = 1/3$ $\quad$ $W_2 = 2/3$

$w_1 = 1/3$ $\quad$ $w_2 = 2/3$ proportional allocation

$w_1 = 2/3$ $\quad$ $w_2 = 1/3$ optimal allocation

Suppose the researcher is seeking a ±5% reliability with 95% confidence, i.e., r = 0.05 and Z = 1.96. The expected $\bar{X}_1 = 500$ and $\bar{X}_2 = 875$. In proportional allocation:

$$\bar{X} = w_1\bar{X}_1 + w_2\bar{X}_2 = (1/3)(500) + (2/3)(875) = 750$$

The value of $s_{\bar{x}}^2$ is:

$$s_{\bar{x}}^2 = \bar{X}^2r^2/Z^2 = (750^2)(0.05)/(1.96^2) = 366$$

The value of n_0 is (without finite population correction):

$$n_0 = \sum_{j=1}^{J} W_j s_j^2/s_{\bar{x}}^2$$

$$= [(1/3)(400^2) + (2/3)(100^2)]/366 = 164$$

With a finite population correction:

$$n = n_0/(1 + n_0/N) = 164/(1 + 164/3000) = 155$$

In optimal allocation:

$$\bar{X} = w_1\bar{X}_1 + w_2\bar{X}_2 = (2/3)(500) + (1/3)(875) = 625$$

The value of $s_{\bar{x}}^2$ is:

$$s_{\bar{x}}^2 = \bar{X}^2 r^2/Z^2 = (625^2)(0.05^2)/(1.96^2) = 254$$

The value of n_0 is (without finite population correction):

$$n_0 = \left[\sum_{j=1}^{J} W_j s_j\right]^2 \div s_{\bar{x}}^2 = [(1/3)(400) + (2/3)(100)]^2 \div 254 = 157$$

With a finite population correction:

$$n = \left[\sum_{j=1}^{J} W_j s_j\right]^2 \div \left[s_{\bar{x}}^2 + \sum_{j=1}^{J} W_j s_j^2/N\right]$$

$$= 200^2 \div [254 + (1/3)(400^2)/3000 + (2/3)(100^2)/3000]$$

$$= 40{,}000/(254 + 20) = 146$$

The number of sample customers in the optimally allocated sample is less than the number of sample customers in the proportionally allocated one. This is despite the fact that the optimal one has a lower required overall sample variance. Optimal allocation can indeed have a higher required variance; it just so happened in this example that it was lower due to the nature of the data. Controlling for the same sample variance ($s_{\bar{x}}^2 = 366$), the optimal sample size for a Neyman allocation sample is:

$$n_0 = (1/366)[(1/3)(400) + (2/3)(100)]^2 = 109$$

With a finite population correction

$$n = 200^2/(366 + 20) = 104$$

Therefore, two-thirds as many meters are needed when the sample is optimally allocated as when it is proportionally allocated. Proper stratification procedures can indeed prove cost-effective.

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APPENDIX C

SAMPLE CUSTOMER SURVEY QUESTIONNAIRES

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SAMPLE CUSTOMER SURVEY QUESTIONNAIRES

The following questionnaires are used by Carolina Power and Light (CP&L) Company in its load research surveys. They are included as illustrations of possible procedures that may be followed. Also reproduced here are CP&L instructions to its interviewers, who completed the questionnaires for commercial and industrial customers. Specifics should be adapted to the organization of the project, the type of survey, the nature of the customers, and the ultimate purposes of the research.

INSTRUCTIONS FOR CUSTOMER INTERVIEWS AND LOAD SURVEY FORMS

When the Customer Service Representatives receive the interview form, the account number and the SIC code number will have already been verified. The customer name, address, and test rate code (GS or LGS) will be on the form. There will be no substitution made in the field. This sample was chosen under very exacting conditions, and it is necessary that these specific customers be sampled. If the customer will not cooperate, return the form to your respective area or district office.

Interviews on those customers selected for testing are scheduled to start on April 8, 1980. The target date for completion of all interviews is June 2, 1980. Installation of recorders on the sample customers will start as soon as the Meter Division receives a request for installation and a completed interview form. It is therefore vital that each completed interview be turned in to your area or district office as soon as the interview is completed and <u>not</u> held until all interviews in an area are completed.

The primary objective of the interview is to explain the program to the customer, get permission to install the test equipment, and <u>complete the interview form</u>. It is important for each interviewer to realize that although we have the legal right to install special metering equipment on any customer, it it <u>absolutely essential</u> that we convince each customer that this study is being run with his cooperation to <u>insure better system planning</u> and to <u>insure continued reliable service</u> for his particular installation. We not only want the data from these specific installations, but we want each customer to feel that we are thinking about him as a customer and that our efforts are directed toward his interests. The need for getting each customer's good will and appreciation for what we are doing cannot be over-emphasized.

Customer interviews and survey forms should be handled in accordance with the instructions for the various customer categories as follows.

<u>General Service (GS) Customers Who Do Not Presently Have Magnetic Tape Metering</u>

All of these customers must be contacted in person to obtain permission to install the test equipment and make the on site survey as necessary to complete the interview forms. Load Research Forms 05020A and B must be thoroughly completed as explained below.

CP&L
FORM 05002
REV. 8/80

CAROLINA POWER & LIGHT COMPANY
RESIDENTIAL LOAD RESEARCH

RETURN BY ____________

ACCOUNT NUMBER

CY	RDO	RT	FOL	T	C

IDENTIFICATION NUMBER ____________

CUSTOMER ____________

ADDRESS ____________

CITY ____________ STATE ____________ ZIP CODE ____________

1. TYPE OF RESIDENCE

			CODE
HOUSE:	1 STORY	☐	1
	2 STORY	☐	2
	SPLITLEVEL	☐	3
	OTHER	☐	4
APARTMENT:	DUPLEX	☐	5
	MULTIPLE	☐	6
	CONDOMINIUM	☐	7
MOBILE HOME:		☐	8

NO. UNITS ________

2. INSULATION

	YES	NO
CEILING	☐	☐
WALLS	☐	☐
FLOOR	☐	☐
STORM WINDOW & DOOR	☐	☐
COMMON SENSE HOUSE	☐	☐

3. SIZE OF RESIDENCE

APPROXIMATELY LIVING AREA ________ SQ. FT.

4. FAMILY

TOTAL NO. LIVING IN RESIDENCE ☐

5. MAJOR ELECTRIC LOAD

NUMBER		NUMBER	
☐	AIR CONDITIONER (ROOM) ________ BTU'S	☐	REFRIGERATOR - FREEZER – MANUAL
☐	AIR CONDITIONER (CENTRAL) ________ TONS	☐	REFRIGERATOR - FREEZER – SELF DEFROSTING
☐	CLOTHES DRYER	☐	FREEZER
☐	CLOTHES WASHER	☐	TELEVISION
☐	DISHWASHER	☐	WATER HEATER – ELECTRIC: WATTS: (TOP) ______ (BOT) ______ GALS ______
☐	FAN (ATTIC)	☐	WATER HEATER – NATURAL GAS
☐	RANGE	☐	WATER HEATER – SOLAR ASSISTED
		☐	DEEP WELL & PUMP

6. HEATING SYSTEM

A. PRIMARY

		TYPE	LOAD	
☐	1	ELECTRIC FURNACE	________	KW
☐	2	HEAT PUMP	________	TONS
☐	3	CEILING CABLE	________	KW
☐	4	BASEBOARD	________	KW
☐	5	OTHER ELECTRIC	________	KW
☐	6	GAS FURNACE		
☐	7	OIL FURNACE		
☐	8	OTHER ____________		TYPE

B. SUPPLEMENTARY

		TYPE
☐	1	WOOD STOVE – FREESTANDING
☐	2	WOOD STOVE – FIREPLACE INSERT
☐	3	FIREPLACE
☐	4	SOLAR
☐	5	OTHER ____________ TYPE

ELIGIBLE FOR CONSERVATION RATE ☐

REMARKS ____________

PERMISSION TO SUBMETER ____________ CUSTOMER ____________ DATE

INTERVIEWED BY ____________ NAME ____________ DISTRICT ____________ OFFICE

FORM NO. 05020A
REV. 3/80
RETURN BY ________

CAROLINA POWER & LIGHT COMPANY
COMMERCIAL INDUSTRIAL
LOAD RESEARCH

ACCOUNT NO. [ ]

IDENTIFICATION NO. [ ] S.I.C [ ]

CUSTOMER ______________________ RATE ________

ADDRESS ______________________

CITY STATE ______________________ ZIP CODE ________

1 TYPE OF CUSTOMER ______________________

A DESCRIBE MAJOR ACTIVITY IN BLDG. ______________________

B PHYSICAL DESCRIPTION OF BLDG

NO. OF STORIES [ ]

NO. SQ. FT FLOOR SPACE
HEATED [ ]

C EXPOSED NO. OF SIDES [ ]

IS ROOF EXPOSED — YES [ ] NO [ ]

2 MAJOR ELECTRIC LOADS

A AIR CONDITIONING

CENTRAL TONS [ ]

WINDOW UNITS TONS [ ]

B LIGHTING

INTERIOR CONN KW [ ]

EXTERIOR KW [ ]

C REFRIGERATION TONS [ ]

D COOKING EQUIPMENT · KW CONN. [ ]

E WATER HEATING

TANK GAL [ ] KW CONN. [ ] GAS BTU'S [ ]

3 HEATING SYSTEMS

NUMBER

[ ] SUPL. HEATING KW CONN. [ ]

[ ] RESIST. HEATING KW CONN. [ ]

[ ] HEAT PUMPS TONS [ ]

[ ] Other ______________________
TYPE – GAS, OIL, WOOD, ETC.

4. MISCELLANEOUS LOADS TOTAL KW CONN. [ ]

5. NUMBER OF OPERATING HOURS PER DAY [ ] NUMBER DAYS PER WEEK [ ]

6. REMARKS ______________________

PERMISSION TO SUBMETER ______________________ DATE ________
CUSTOMER

INTERVIEWED BY ________ DISTRICT ________ OFFICE ________

C.P.&L.CO.
FORM NO. 050208
REV. 2/74

CAROLINA POWER & LIGHT COMPANY
COMMERCIAL - INDUSTRIAL
LOAD RESEARCH

TYPE OF SERVICE:

WIRE ____________ PHASE ____________ VOLTS ____________ DELTA ____________ WYE ____________

METER BASE MFG. ____________ TYPE ____________ AMPS ____________ TYPE BY-PASS ____________

MOUNTING:

WALL SURFACE ____________ WALL RECESSED ____________ POLE ____________

OTHER ____________ SIZE CONDUIT ____________ SIZE ROMEX ____________

LOCATION ____________

____

____

SKETCH SERVICE:

1. Type of Customer - State the nature of the customer's business that most accurately describes the type of operation, such as food store, restaurant, branch bank, office building, etc. In keeping with a new requirement, it is imperative that commercial office buildings be identified on the basis of the attached definition and indicated by type. For examples, office building (lawyer's office), office building (central headquarters for insurance or banking organizations), office building (rental space for professionals), etc.

   Buildings in which services of a commercial nature are provided are not office buildings by definition and should be listed according to their identifying type, such as branch bank, branch insurance agency, real estate agency, etc.

   1A. Describe Major Activity in Building - In addition to stating major activity, such as banking, furniture retailing, auto servicing, etc., it is desirable to note here anything unique or descriptive about the building or operations associated with the building under consideration. For example, assuming the major activity of a county office building to be "general administrative noncommercial services," it would be helpful to know that the building also houses a restaurant, courtrooms, jail, parking deck, etc. Or, it would be helpful to know that a large greenhouse for research purposes estimated at 200 KW is included on the meter supplying a given building. Anything you can add that might help interpret the consumption of electricity or clarify an unusual condition will be helpful.

   It is important that the description only cover that space which is being served by an individual meter. For example, where a complex has three or four meters, the description should only cover the area served by one meter. It might be well to note the rest of the complex, but make it clear what is served by this meter.

   1B. Physical Description of Building - This is self-explanatory. It is satisfactory to step off the dimensions of the area to obtain the square footage.

   1C. Exposed No. of Sides-is Roof Exposed - Self-explanatory.

2. Major Electric Loads

   2A. Air Conditioning - The most accurate information possible should be obtained due to the importance of this load.

   2B. Lighting - The connected lighting should be the primary lighting that is used during the hours of operation. Do not include any lighting that has been de-energized due to conservation reasons. Insignificant lighting such as small signs, small advertisements or minor displays can be ignored.

   2C. Refrigeration - Self-explanatory.

   2D. Cooking Equipment - Note in space beneath "D" the appropriate frequency of use.

2E. Water Heating - Do not include booster heaters in the information boxes but note boosters separately as to number and KW in the space beneath "E." Solar equipment should also be noted.

3. Heating Systems - Be sure to list all systems if more than one is installed. Also, if a combination of electricity and other fuels are used, state the approximate percentage of the space that is being heated by other fuels. This can be included as a part of the information supplied on the "other" fuel line by adding a notation, such as "25% of building." Solar heating should also be noted.

4. Miscellaneous Loads - This should include major demand producing equipment other than the loads specifically listed above.

5. Number of Operating Hours Per Day - Per Week - Self-explanatory.

6. "Remarks." - List here any additional information which you think might be advantageous in interpreting this data. If more room is needed, use the back of the page.

Permission to Submeter - It is not necessary for the customer to sign this form; and, in fact, he should not be asked to do so. You should be absolutely certain that the customer is agreeable and understands the purpose of this special equipment and that it will in no way influence his billing meter nor his bill. It is necessary, however, to write down the name of the person who gave you permission to install this metering equipment. When you return this form completed, it will be assumed that it is perfectly agreeable with this individual to install this equipment and that, for all practical purposes, he has the authority to make this decision. Again, a great deal of judgment and knowledge of your customers will be necessary.

Type of Service - Mounting - Complete Form No. 05020B to include a sketch of the service entrance and add any information you feel would be helpful to the meter group. This information will be used by them to preassemble test equipment.

The meter groups are not as familiar with the addresses in the districts as you are. If you would put on the interview form (use back if necessary) details of how to reach the customer's location and include a sketch, it will save a lot of cross-checking on the part of the meter installer. This is very important and will be of great help to the meter groups. Be specific.

General - These interviews should be made as quickly as is reasonably possible and should be turned in to your respective area or district office the day that they are completed. There is a great deal of mechanical work in adapting these special meters to the particular installations; and, of course, a great deal of work is required to install them. It is impossible to do this in a few days. As soon as you have completed a single interview, the Meter Section can start on that one. Turn in that form and start on the next interview. Please make every attempt to get these interviews completed and returned as soon as possible.

General Service (GS) Customers Who Presently Have Magnetic Tape Metering

These few customers can be identified by the entry "Billing Customer" on the survey form in the upper right hand corner. This means that this customer is now being metered using the magnetic tape metering package and is being billed on the magnetic tape data.

Although the necessary testing equipment has already been installed, these customers must be contacted in person to obtain permission to use the data for load research purposes and, make an on site survey in order to complete interview Form 05020A. All items on Form 05020A must be completed in accordance with the instructions as provided for GS customers without magnetic tape metering. It is not necessary to fill out Form 05020B.

Large General Service (LGS) Customers (Commercial and Industrial)

These customers should be contacted by phone or in person and advised of the Company's plans to install two track magnetic tape metering on an interim basis for load research purposes. Four track magnetic tape metering is planned to be installed at a later date, on a permanent basis, when the equipment becomes available for the few remaining LGS customers who do not presently have four track magnetic tape metering.

The information required on the survey forms is minimal. For Form 05020A, complete items 1, 1A, (3 for office buildings only) and 5. Complete all of Form 05020B including a sketch of the service entrance equipment and meter and customer location directions as necessary. Please observe the definition for a commercial office building and abide by the applicable instructions as explained previously.

DEFINITION OF COMMERCIAL OFFICE BUILDING

A separately metered building in which the primary activity in the majority of the space consists of performing noncommercial services of a general administrative or professional nature such as clerical, record keeping, consulting, support and managerial functions.

Examples include: Buildings in which space is rented to others primarily for administrative or professional use; central office and headquarters buildings used primarily for management, support and other administrative purposes, such as those occupied by large insurance, banking and utility firms or chain operations; governmental buildings (federal, state, county, city, town or local) used primarily for administrative purposes when other uses are supplemental or secondary in purpose; and, miscellaneous or small buildings used for administrative or professional purposes, such as Chambers of Commerce, merchants/business/education associations, political/social/civic organizations, law offices, employment offices, doctors' offices, engineers'/architects' offices and other similar type offices.

An office building may house commercial services, such as banking, retailing, food service, court rooms, postal facilities, jail facilities, travel agencies, research facilities, etc., within this definition, if the combined services and occupied space of such operations account for a secondary portion of the building's primary activity and total space available.

Buildings in which the primary activity consists of providing services of a commercial nature are excluded from this definition, such as branch banks, branch or independent insurance agencies, travel agencies, financial agencies, investment agencies, branch post offices, real estate agencies, subordinate court houses, communication agencies, branch utility offices, brokerage offices, etc.

APPENDIX D

SAMPLE RECORDING PROCEDURES

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SAMPLE RECORDING PROCEDURES

This appendix includes documentation on several procedures used by Carolina Power and Light Company (CP&L) for installing metering equipment and changing recording tapes. The specifics would vary for different utilities, depending on the organization of the load research effort, the type of survey, the customers involved, and the type of equipment installed.

When equipment is installed, the installer fills out a recorder installation form and a recorder location master. Whenever tapes are changed, a load research reading card is completed. For substation metering, a substation magnetic tape reading document is used instead. These four forms are reproduced on the following pages. Also presented here are overall CP&L procedures for processing load research customers and forms and instructions for completing the load research reading cards. Sample tape installation instructions are displayed for Sangamo and Duncan cassette recorders and Westinghouse cartridge recorders. Other tape changing procedures also are discussed, and the processing of tapes and reading cards is described.

PROCEDURE FOR PROCESSING LOAD RESEARCH CUSTOMERS FOR PHASE I OF THE 1980-82 LOAD RESEARCH PROJECT

Immediately upon receipt of the Customers Selected for Load Study listing, the following procedures should be completed:

I. Customer Verification

1. Key the Revenue Account Number from the customer listing into the CAIS terminal.
2. Verify that the selected customer is still located at the designated location.
3. Verify that the account is still active (also check for a pending disconnect on the "ACTY" screen).
4. If you cannot locate the selected customer at the designated address, or if the account is no longer active, please call the Rates and Service Practices Department in Raleigh for further instructions.

II. Processing the Interview Forms

1. Prepare two copies of the "Commercial-Industrial Load Research" interview form (Form 5020A & B) by completing the following items.
   a. ACCOUNT NUMBER - Enter complete Revenue Account Number.
   b. IDENTIFICATION NUMBER - Do not mark (will be filled in by Load Research Unit).
   c. SIC CODE - Enter current SIC Code.
   d. CUSTOMER - Enter the customer's name.
   e. RATE - Enter the rate code (GS or LGS) from the selection list.
   f. ADDRESS - Enter street name and number for service address.
   g. CITY, STATE - from service address.

C. P. & L. CO.
FORM NO. 05030
REV. 3/80

CAROLINA POWER & LIGHT COMPANY
LOAD RESEARCH RECORDER
INSTALLATION/REMOVAL

☐ INSTALLATION

☐ REMOVAL

LOCAL OFFICE ______ DATE ______ RANDOM NO. ______

RECORDER LOCATION ID	NAME	REVENUE ACCOUNT NO. (CY RDO RT FCL T C)

SERVICE ADDRESS	SERVICE CITY AND STATE	S.I.C.	TD

DIRECTIONS TO PREMISES ______

SUR. GP.	RV CL	RT. CD.	LD CH	STATE	RATE	ZONE NUM.	SUM	WIN	OPK

INITIATING METER

① CHANNEL ______ ② USE CODE [1]

CO. NO. ______ SERIAL NO. ______

MAKE ______ TYPE ______ CHASSIS NO. ______

AMPS ______ VOLTS ______

WIRE ______ PHASE ______ Kh ______ PKh ______

TYPE INITIATOR ______ R / I ______

CONTACT RESISTANCE ______ OHMS

KWH INDEX ______ ③ CONSTANT ______

NO. OF DIALS ___ [4] ___ [5] ___ [6]

REVENUE METER

CO. NO. ______ SERIAL NO. ______

MAKE ______ TYPE ______

AMPS ______ VOLTS ______

WIRE ______ PHASE ______ Kh ______ PKh ______

TYPE INITIATOR ______ R / I ______

CONTACT RESISTANCE ______ OHMS

KWH INDEX ______ CONSTANT ______

NO. OF DIALS ___ [4] ___ [5] ___ [6]

RECORDER

CO. NO. ______ ④ SERIAL NO ______

MAKE ______ ⑤ TYPE ______ CIRCUIT NO. ______

COUNTER INDEX ______ ⑥ CONSTANT ______

⑦ COUNTER DIALS ___ [0] ___ [4] ___ [5] ___ [6] ___ [7] ___ [8]

③ BATTERY CARRY OVER ___ YES [1] ___ NO [0] BATT. NO. ______

AUXILIARY CT RATIO ______ TERM VOLTAGE ______

③ INT./HR. 15 MIN. ___ [4] 30 MIN. ___ [2] 60 MIN. ___ [1]

DEMAND DEVICE

CO. NO. ______ SERIAL NO. ______

MAKE ______ TYPE ______

COUNTER INDEX ______ CONSTANT ______

KW INDEX ______ CONSTANT ______

PT RATIO ______ CT RATIO ______

TYPE OF SERVICE WIRE ______ PHASE ______ VOLTS ______ DELTA ______ WYE ______

METER BASE MFG ______ TYPE ______ AMPS ______ TYPE BY-PASS ______

MOUNTING: WALL SURFACE ______ WALL RECESSED ______ POLE ______

OTHER: ______ SIZE CONDUIT ______ SIZE ROMEX ______

LOCATION: ______

______

UNIT FORM: TYPE ADAPTER ______ TYPE TROUGH ______

RECORDER MOUNTING: ON TROUGH ______ ON WALL ______ ON SERVICE ENTRANCE BELOW ______

ON SERVICE ENTRANCE ABOVE ______ PEDESTAL ______ WALL (TYPE) ______

OTHER: ______

______

REMARKS: ______

______

______

______

______

WORK DONE BY ______ DATE ______ TIME ______

FORM NO. 05005
REV. 6/80
RET. - 6 Months

LOAD SURVEY
RECORDER LOCATION MASTER

CP&L CC

UPDATE
- [ ] MASTER
- [ ] TOTALIZED
- [ ] MAINFRAME

RECORDER LOCATION ID

TRANS 11 I.D. 0 1

NAME

REVENUE ACCOUNT NO.
CY RDO RT FOL T C

SURVEY GROUP NO.

REVENUE CLASS

RATE CODE

APPLIANCE GROUP CD

REVENUE METER

KWH CONSTANT

NUMBER OF DIALS 4 5 6

TRANS 12 I.D. 0 1

SERVICE ADDRESS

SERVICE CITY AND STATE

SIC CODE

TYPE DELIVERY

ANALYSIS KEY

TRANS 13 I.D. 0 1

INITIATING METER

RECORDER

CHANNEL	
	A
	B
	C

USE CODE

CONSTANT

DIALS	
	4
	5
	6

SERIAL NO.

TYPE

CONSTANT

DIALS 0 5 6 7 8

INT/HR 15 MIN 4 30 MIN 2 60 MIN 1

BATTERY CARRY OVER

NO	0
YES	1

CHANNEL	
	A
	B
	C

USE CODE

CONSTANT

DIALS	
	4
	5
	6

SERIAL NO.

TYPE

CONSTANT

DIALS 0 5 6 7 8

INT/HR 15 MIN 4 30 MIN 2 60 MIN 1

BATTERY CARRY OVER

NO	0
YES	1

CHANNEL	
	A
	B
	C

USE CODE

CONSTANT

DIALS	
	4
	5
	6

SERIAL NO.

TYPE

CONSTANT

DIALS 0 5 6 7 8

INT/HR 15 MIN 4 30 MIN 2 60 MIN 1

BATTERY CARRY OVER

NO	0
YES	1

TRANS 14 I.D. 0 1

AMPERAGE CONSTANT

REMARKS

WORK DONE BY DATE TIME

FORM 05001
REV. 7/75

LOAD RESEARCH READING CARD

CP&L CO.

1 RECORDER SERIAL NO. ____________ TAPE SERIAL NO. ____________

CUSTOMER ____________

ADDRESS ____________

CITY ____________ STATE ____________

2 RECORDER: 2 1

3 IDENTIFICATION NUMBER

ACCOUNT NO.

CY	RDO	RT	FOL	T	C

4 TRANSACTION 90

REGISTER READINGS

5 CHANNEL A

REVENUE METER

STOP 6

START 7

NET 8

KWH CONST. ____________

TOTAL KWH ____________

INITIATING METER

STOP 9

START 10

NET 11

KWH CONST. ____________

TOTAL KWH ____________

PULSE CONST. ____________

TOTAL PULSES ____________

TIME READINGS

STOP

12 DATE

MO	DA	YR

TIME : A.M. P.M.

DAY OF WEEK S M T W T F S
CIRCLE

START

13 DATE

MO	DA	YR

TIME : A.M. P.M.

DAY OF WEEK S M T W T F S
CIRCLE

ENTER ACTUAL TIME IF DIFFERENT FROM RECORDER CLOCK.

TIME : A.M. P.M.

POWER INTERRUPTION REPORT
4A TRANSACTION 91

5A FROM ____________ DATE TIME ____________ A.M. P.M.

6A TO ____________ DATE TIME ____________ A.M. P.M.

7A FROM ____________ DATE TIME ____________ A.M. P.M.

8A TO ____________ DATE TIME ____________ A.M. P.M.

9A TOTAL TIME ____________ HRS ____________ MIN

FORM 050(1)
(REVERSE)

TAPE INSTALLED BY ______________________________

TAPE REMOVED BY ______________________________

READING CARD VERIFIED BY ______________________ DATE __________

REMARKS:

TRANSLATION LOG

DATE __________ OPERATOR ______________

TRANS PULSES		TRANS. INTV	
TOTAL PULSES		TOTAL INTV.	
DIFF.		DIFF.	
LAST MOS. DIFF.		LAST MOS. DIFF.	

MAINTENANCE CALL

WORK DONE BY ______________________ DATE __________

TIME __________

WORK DONE: ______________________________

FORM NO. 05021
REV. 4/78

SUBSTATION MAGNETIC TAPE
READING DOCUMENT

CP&L CO.

1 RECORDER SERIAL NO. ______________ TAPE SERIAL NO. ______________

CUSTOMER ______________

ADDRESS ______________

CITY ______________ STATE ______________

2 RECORDER	3 IDENTIFICATION NUMBER	ACCOUNT NUMBER
		CY 0,0 | FDO 0,0,0 | RT 0,0 | FOL 0,0,0 | T C 0 0

REGISTER READING	TIME READING
4 TRANS. 89 5 CHANNEL A METER 6 / 7 / 8 — RECORDER 9 STOP 0; 10 START 0; 11 NET 0 CONST. ______ TOTAL ______ TRANS. PULSES ______ MAX 15 MIN. KW ______	4 TRANS. 88 STOP 5 DATE (MO DA YR) — RECORDER 6 TIME : AM PM DAY OF WEEK (CIRCLE) S M T W T F S START 7 DATE (MO DA YR) — RECORDER 8 TIME : AM PM DAY OF WEEK (CIRCLE) S M T W T F S
4 TRANS. 89 5 CHANNEL B METER 6 / 7 / 8 — RECORDER 9 STOP 0; 10 START 0; 11 NET 0 CONST. ______ TOTAL ______ TRANS. PULSES ______ MAX 15 MIN. KW ______	COMPUTED INTERVALS ______ 12 ENTER ACTUAL WATCH STOP TIME TIME : AM PM
	PARTIAL SEQUENCE 9 ☐
4 TRANS. 89 5 CHANNEL C METER 6 / 7 / 8 — RECORDER 9 STOP 0; 10 START 0; 11 NET 0 CONST. ______ TOTAL ______ TRANS. PULSES ______ MAX 15 MIN. KW ______	4A TRANS. 91 POWER INTERRUPTION REPORT 5 FROM ______ DATE TIME ______ AM PM 6 TO ______ DATE TIME ______ AM PM 7 FROM ______ DATE TIME ______ AM PM 8 TO ______ DATE TIME ______ AM PM 9 TOTAL TIME ______ HRS ______ MIN

FORM 05021
(REVERSE)

TAPE INSTALLED BY ______________________________

TAPE REMOVED BY ______________________________

READING DOCUMENT VERIFIED BY: ______________________________ DATE ______________

REMARKS:

TRANSLATION LOG

DATE ______________		OPERATOR ______________	
TRANS PULSES		TRANS. INTV	
TOTAL PULSES		TOTAL INTV.	
DIFF.		DIFF.	
LAST MOS. DIFF.		LAST MOS. DIFF.	

MAINTENANCE CALL

WORK DONE BY ______________________________ DATE ______________

TIME ______________

WORK DONE: ______________________________

h. ZIP CODE - from service address.

i. DISTRICT - Enter the name of your district in the appropriate space on the bottom line of the form.

j. OFFICE - Enter your office name in the appropriate space on the bottom line of the form.

k. Please make the notation "REV. CLASS" just below the IDENTIFICATION NUMBER block and place the correct Revenue Class Code (42-Commercial, 43-Industrial, etc.) beside it. Example: REV. CLASS 42.

2. Check for an asterisk "*" immediately to the left of the Revenue Account Number on the Customers Selected for Load Study listing indicating that this account is a "Billing Customer." If this notation is found, please write "Billing Customer" in the upper right-hand corner of the "Commercial-Industrial Load Research" form (Form 5020A). Prepare one copy of Form 5020A, as per the instructions in "a" through "j" above.

   Note: Since a recorder has already been installed on these "Billing Customers," it will not be necessary to use Form 5020B.

3. Deliver prepared form(s) to the Customer Service Representative responsible for conducting the interview.

PROCESSING COMPLETED COMMERCIAL-INDUSTRIAL LOAD RESEARCH FORMS FOR PHASE I OF THE 1980-82 LOAD RESEARCH PROJECT

When the Customer Services Representative has completed the interview with the customer, the interview form (Form 5020A & B original and copy) will be returned to the field office. Proceed as follows:

1. Determine from the remarks and notations on the interview form if the customer has agreed on the installation of a recorder. If he has refused, if a problem exists with the installation of a recorder, or if the account is no longer active, contact the Rates & Service Practices Department in Raleigh for further instructions.

2. If the customer has agreed to participate in the Load Research Study, review the interview form(s) for completeness, as follows:

   a. Form 5020A

      1. Every item on the form should be completed for all General Service (GS) customers except the GS customers in the Industrial Class (43).

      2. Items 1, 1A, 3 (for office buildings), 5, "PERMISSION TO SUBMETER," "DATE," AND "INTERVIEWED BY" should be completed for all Large General Service (LGS) customers and the General Service (GS) customers in the Industrial Class (43).

b. Form 5020B

All necessary items should be completed (including a service entrance sketch and directions to the premises, when necessary) for the customers that require the installation of a recorder (all "Nonbilling" customers).

3. The signature of the Area Manager or his appointed representative in the space below the name of the office at the bottom of the interview form will be required to indicate that the processing procedure has been completed.

4. If the previous checks indicate that a recorder is to be installed, prepare the "Load Research Recorder Installation/Removal" form (Form 05030, Rev. 3/80) for the customer. The form should be prepared in original and one copy.

   Note: This will not be necessary if the customer is a "Billing Customer" since a recorder has already been installed.

5. The following items should be completed on Form 05030:

   a. LOCAL OFFICE - Enter the name of the office from which the customer is served.

   b. DATE - Enter the date the form is prepared.

   c. RANDOM NUMBER - Enter Random Number as it appears on Customers Selected for Load Study listing.

   d. RECORDER LOCATION ID - This block will be filled in by the Rate Department in Raleigh.

   e. NAME - Enter the customer's name exactly as it appears on the CAIS terminal.

   f. REVENUE ACCOUNT NO. - Enter the revenue account number as it appears on the CAIS terminal, including check digit.

   g. SERVICE ADDRESS - Enter the service location address.

   h. SERVICE CITY AND STATE - Self-explanatory.

   i. SIC CODE - Enter SIC Code as it appears on the CAIS terminal.

   j. TYPE DELIVERY CODE - This block will be filled in by the Rates & Service Practices Department in Raleigh.

   k. DIRECTIONS TO PREMISES - Give directions to the premises if the service location address is not descriptive enough.

   l. REVENUE METER - Enter the Company meter number and the manufacturer's serial number of the meter shop serving the customer's premises.

6. Make a notation on the "Customers Selected for Load Study" listing indicating the recorder installation request was prepared. If the customer was rejected for some reason, mark through the name.

7. Distribution of Completed Forms - "Nonbilling" Customers.

   a. Send the original of the completed interview form (Form 5020A & B) to the Rates & Service Practices Department in Raleigh.

b. Send a copy of the completed interview form (Form 5020A & B) along with the original and a copy of the Load Research Recorder Installation/Removal form (Form 05030) to the Division Meter Shop.

8. Distribution of Completed Forms - "Billing" Customers.

Send completed interview form (Form 5020A) to the Rates & Service Practices Department in Raleigh.

Note: As the forms for each sample customer are completed, they should immediately be forwarded to the Division Meter Shop or the Rates & Service Practices Department, as applicable, and not held until the forms for all sample customers are completed.

9. File the "Customers Selected for Load Study" listing for future reference.

INSTRUCTIONS FOR PREPARATION OF LOAD RESEARCH READING CARDS (FORM 05001)

When the load research recorders in your area are installed, a tape cartridge or tape cassette will be installed, a reading card completed and the recorder started by Division Meter Personnel. Subsequent changing and processing of the tapes and reading cards should be performed by the designated office and field personnel.

When the recorders have been installed, the Rates and Service Practices Department will prepare a MASTER SET of reading cards and send them to you. This set of reading cards should be used as a guide in the preparation of a new set each month. Do not send the MASTER SET out for readings to be recorded on them. A two month supply of blank reading cards will be furnished by the Rates and Service Practices Department. Note: Additional load research reading cards - Form No. 05001- should be ordered from the General Stationery Warehouse - catalog No. 031-00013.

Tape cartridges and cassettes should be changed on the dates specified by the Rates and Service Practices Department. These dates are carefully selected to insure that the tape will cover the entire period between changes. A list of these change dates will be furnished to each office.

On or near the first of each month, prepare a new set of reading cards for that month. The following procedure should be followed:

1. Check the MASTER SET reading card to be sure that any changes such as recorder type, pulse constant, etc., have been entered. (Note: If a xerox copy of the MASTER SET reading card is used, make sure it is an updated copy and that it is completely legible.)

2. Transcribe the following information from the MASTER SET reading card to a blank reading card.

   A. Recorder serial number
   B. Recorder type - WR-2, WR-31, Sangamo or Duncan
   C. Customer Name

D. Address
E. City
F. State
G. Identification Number
H. Account Number
I. Revenue Meter KWH Constant
J. Initiating Meter KWH Constant
K. Pulse Constant

3. Check each card to be certain that all information has been transcribed correctly.

When the reading cards for the month have been completed, they should be delivered to the persons responsible for changing the tapes along with the blank cartridge or cassette. Make certain that there are enough of the correct type of blank cartridges and cassettes on hand. Your office should have the required number of tape cartridges and cassettes no later than the day before the scheduled change. If you have not received the required tapes by this time, please notify the Rates and Servie Practices Department.

The reading card you have just prepared will be left in the recorder with the tape during the month while data is being recorded.

Make certain that the persons responsible for changing the tape are aware of the scheduled change date and any special applicable information such as time changes from DST to EST and vice versa.

Each person changing a tape should have the following items when changing a tape (also see the tape removal check list):

1. Reading card.
2. Appropriate blank tape cartridge or cassette for the type recorder as shown on reading card.
3. Watch (set to the correct time of day).
4. "Load Research Tape Installation Procedures" for appropriate type of recorder.
5. Magnetic tape head cleaner (may be ordered from General Warehouse - catalog number 30580708).
6. Clean lint free cloth such as a chammy cloth (may be locally purchased).

Tape Removal Check List

1. Do not make time readings when point is in the black area.
2. Turn capstan 5 revolutions before removing tape.
3. Record stop time AM or PM and date.
4. Read both meters and check total KWH after multiplying by KWH constant.
5. Clean and inspect bias-magnet head and capstan.

6. Insert new cartridge and check alignment marks.
7. Turn capstan 5 revolutions.
8. Record new tape serial number on new card.
9. Record stop readings as start readings on new card.
10. Record new tape serial number on new card.
11. Sign both cards.
    Note: For detailed instructions refer to tape installation procedures.

TAPE INSTALLATION PROCEDURES FOR SANGAMO CASSETTE RECORDER

1. Visually inspect kilowatt-hour meter to see that the meter is operating.

2. Open door to recorder. Pull out reading card from clip inside the door. Check tape serial number on card to see that it agrees with tape cassette serial number; also check recorder serial number.

3. Check interval timer. If pointer is in the black area DO NOT change tape cartridge or take time readings! Wait until pointer is out of the "black." All recorded times on reading card should be at least three minutes before quarter hour or three minutes after quarter hour.

   Examples of correct readings: 11:04, 1:34, 2:48, 12:18, 2:52

   Examples of incorrect readings: 11:00, 1:30, 2:45, 12:15

4. If pointer is not in the "black" and the recorder clock is indicating the correct time of day the following steps should be followed.

   A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of week on removed reading card.

   B. Read the STOP reading from kilowatt-hour meter and record in the INITIATING METER section of the reading card. Read all dials.

   C. Enter the word SAME beside the words REVENUE METER on the reading card.

   D. When the minute hand is not in the "black" area, lift the recording mechanism to latch in the raised position; lower the cassette latch and remove cassette tape; place in cassette case.

   E. Inspect tape guide pins and recorder head for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean. NOTE: Magnetic tape head cleaner is listed in General Warehouse catalog, number 30580708.

   F. (1) Install the new casette tape over the cassette guide pins and push to engage cassette latch.
   (2) Rotate the advance hub clockwise until the supply hub also rotates clockwise. Observe that the supply hub on the left hand side is full of tape and the oxide coated tape is visible in the cassette opening.
   (3) Lift, then lower the recording mechanism.

G. On new reading card write the new tape cassette serial number in proper space. Record the STOP reading for the kilowatt-hour meter as START reading in the INITIATING METER section on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert under clip in the recorder door. NOTE: Recorder TIME must be the recorder clock time when new cassette tape was installed in the recorder.

H. Compute net reading for the kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

NOTE: If Step 4 was followed, skip Step 5 and go to Step 6.

5. If pointer is not in the "black" and the recorder clock indicates a different time than regular clock plus or minus 5 minutes, the following procedures should be followed:

A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of week on removed reading card.

B. Record correct time of day in space provided.

C. Read the STOP reading from kilowatt-hour meter and record in the INITIATING METER section of the reading card. Read all dials.

D. Enter the word SAME beside the words REVENUE METER on the reading card.

E. When the minute hand is not in the black area, lift the recording mechanism to latch in the raised position; lower the cassette latch, remove the cassette tape and place in cassette case.

F. Set the recorder time before inserting cassette. The recorder time may be set simply by turning the interval knob. The interval pointer should be set on zero when hour hand is moved. With interval pointer set on zero, the hour pointer should be set on the hour and the remaining portion set using the interval knob in order to maintain synchronism of the two hands.

G. Inspect tape guide pins and recorder head for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean.

H. (1) Install new cassette tape over the cassette guide pins and push to engage cassette latch.
(2) Rotate the advance hub clockwise until the supply hub also rotates clockwise. Observe that the supply hub on the left hand side is full of tape and the oxide coated tape is visible in the cassette opening.
(3) Lift, then lower the recording mechanism.

I. On new reading card write the new tape cassette serial number in proper space. Record the STOP reading for the kilowatt-hour meter as START reading in the INITIATING METER section on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert under clip in the recorder door. NOTE: Recorder TIME must be the recorder clock time when new cassette tape was installed in the recorder.

J. Compute net reading for the kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

K. A complete investigation should be made to détermine when power interruption occurred and how long it lasted. Record information in spaces 5A, 6A, 7A, 8A, and 9A as needed.

L. Check with Area Office to see what information is available on the power interruption. Attach a note giving all details on the interruption that are available.

6. Close door to recorder and lock.

7. Sign on the back of the removed reading card and place it behind cassette in cassette case. Return tape with card to Area Office.

8. Report any unusual or abnormal conditions to Division Meter Shop.

9. Make a notation on the back of the removed reading card describing the unusual or abnormal condition and that the Division Meter Shop has been notified.

TAPE INSTALLATION PROCEDURES FOR DUNCAN CASSETTE RECORDER

1. Visually inspect kilowatt-hour meter to see that the meter is operating.

2. Open door to recorder. Pull out reading card from clip inside the door. Check tape serial number on card to see that it agrees with tape cassette serial number; also check recorder serial number.

3. Check interval timer. If pointer is in the black area DO NOT change tape cartridge or take time readings! Wait until pointer is out of the "black." All recorded times on reading card should be at least three minutes before quarter hour or three minutes after quarter hour.

   Examples of correct readings: 11:04, 1:34, 2:48, 12:18, 2:52

   Examples of incorrect readings: 11:00, 1:30, 2:45, 12:15

4. If pointer is not in the "black" and the recorder clock is indicating the correct time of day the following steps should be followed:

   NOTE: If recorder clock is indicating wrong time of day go to Step 5.

   A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of week on removed reading card.

   B. Read the STOP reading from kilowatt-hour meter and record in the INITIATING METER section of the reading card. Read all dials.

   C. Enter the word SAME beside the words REVENUE METER on the reading card.

   D. When the minute hand is not in the "black" area, lift the recording mechanism slide bar to the latch position; pull cassette outward from the top and lift out; place in cassette case.

E. Inspect tape guide pins, bias magnet, and recorder head for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean. NOTE: Magnetic tape head cleaner is listed in General Warehouse catalog, number 30580708.

F. (1) Install the new cassette tape by placing the bottom of the tape in the retaining block and pushing the tape over the guide pins.
(2) Rotate the tape advance knob counterclockwise until the supply hub also rotates counterclockwise. Observe that the supply hub on the right hand side is full of tape and the oxide coated tape is visible in the cassette opening. NOTE: The tape advance knob should never be turned when the recording mechanism slide bar is in the record (down) position.
(3) Lift, then lower the recording mechanism slide bar.

G. On new reading card write the new tape cassette serial number in proper space. Record the STOP reading for the kilowatt-hour meter as START reading in the INITIATING METER section on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert under clip in the recorder door. NOTE: Recorder TIME must be the recorder clock time when new cassette tape was installed in the recorder.

H. Compute net reading for the kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

NOTE: If Step 4 was followed, skip Step 5 and go to Step 6.

5. If pointer is not in the "black" and the recorder clock indicates a different time than regular clock plus or minus 5 minutes, the following procedures should be followed.

A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of the week on removed reading card.

B. Record correct time of day in space provided.

C. Read the STOP reading from kilowatt-hour meter and record in the INITIATING METER section of the reading card. Read all dials.

D. Enter the word SAME beside the words REVENUE METER on the reading card.

E. When the minute hand is not in the black area, lift the recording mechanism slide bar to the latch position; pull cassette outward from top and lift out; place in cassette case.

F. Set the recorder time before inserting cassette. The recorder time may be set simply by turning the minute interval and the hour interval knobs. The minute interval pointer should be set on zero when hour hand is moved. With minute interval pointed on zero the hour pointer should be set on the hour and nearest 15 minute division prior to the time desired. Then rotate the minute pointer clockwise to obtain any additional minutes to arrive at the exact time.

G. Inspect tape guide pins, bias magnet and recorder head for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean.

H. (1) Install new cassette tape by placing the bottom of the tape in the retaining block and pushing the tape over the guide pins. (2) Rotate the tape advance knob counterclockwise until the supply hub also rotates counterclockwise. Observe that the supply hub on the right hand side is full of tape and the oxide coated tape is visible in the cassette opening. NOTE: The tape advance knob should never be turned when the recording mechanism slide bar is in the record (down) position.
(3) Lift, then lower the recording mechanism slide bar.

I. On new reading card write the new tape cassette serial number in proper space. Record the STOP reading for the kilowatt-hour meter as START reading in the INITIATING METER section on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert under clip in the recorder door. NOTE: Recorder TIME must be the recorder clock time when new cassette tape was installed in the recorder.

J. Compute net reading for the kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

K. A complete investigation should be made to determine when power interruption occurred and how long it lasted. Record information in spaces 5A, 6A, 7A, 8A, and 9A as needed.

L. Check with Area Office to see what information is available on the power interruption. Attach a note giving all details on the interruption that are available.

6. Close door to recorder and lock. NOTE: If the recording mechanism slide bar is not lowered by the installer, or fails to lower because the cassette is not properly seated, a post in the case lid should hit the tail of the slide bar and prevent closure. This is only a warning that something was overlooked - DO NOT FORCE LID TO CLOSE.

7. Sign on the back of the removed reading card and place it behind cassette in cassette case. Return tape with card to Area Office.

8. Report any unusual or abnormal conditions to Division Meter Shop.

9. Make a notation on the back of the removed reading card describing the unusual or abnormal condition and that the Division Meter Shop has been notified.

TAPE INSTALLATION PROCEDURES FOR WESTINGHOUSE RECORDERS

1. Visual Inspecton

   A. WR-2C Westinghouse recorder (Installed primarily on commercial/industrial customers). Visually inspect revenue meter and initiating meter to see that both meters are operating.

   B. WR-31 Westinghouse recorder (Installed on residential customers and has only one meter). Visually inspect kilowatt-hour meter to see that the meter is operating.

2. Open door to recorder. Pull out reading card from clips on tape cartridge. Check tape serial number on card to see that it agrees with tape cartridge serial number; also check recorder serial number.

3. Check interval timer. If pointer is in the black area DO NOT change tape cartridge or take time readings! Wait until pointer is out of the "black." All recorded times on reading card should be at least three minutes before quarter hour or three minutes after quarter hour.

   Examples of correct readings: 11:04, 1:34, 2:48, 12:18, 2:52

   Examples of incorrect readings: 11:00, 1:30, 2:45, 12:15

4. If pointer is not in the "black" and the recorder clock is indicating the correct time of day the following steps should be followed:

   NOTE: If recorder clock is indicating wrong time of day go to Step 5.

   A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of week on removed reading card.

   B. Read and record STOP readings from initiating meter. Read all dials.

   C. Read and record STOP readings from revenue meter. Read all dials.

      NOTE: Where only one meter is used (Residential Westinghouse WR-31 recorder):

      (1) Read the STOP reading from the kilowatt-hour meter and record in the INITIATING METER section of the reading card.
      (2) Enter the word SAME beside the words REVENUE METER on the reading card.

   D. Turn tape advance knob 5 full turns in direction of arrow. Press the back edge of cartridge toward the tape advance knob (Capstan knob) and lift cartridge away from locking posts. Remove from recorder.

   E. Inspect the tape guide, recorder head and bias magnet for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean. NOTE: Magnetic tape head cleaner is listed in General Warehouse catalog, number 30580708.

   F. Insert the new tape cartridge into recorder. Turn the tape advance knob 5 full turns in direction of arrow.

G. On new reading card write the new tape cartridge serial number in proper space. Record the STOP readings for revenue and initiating meters as START readings on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. NOTE: Recorder TIME must be the recorder clock time when the new tape cartridge was installed in the recorder. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert in clips on tape cartridge.

H. Compute net readings:

(1) When the recorder installation has two meters (Westinghouse WR-2C recorder with revenue meter and initiating meter), compute the net readings for revenue and initiating meters on removed reading card. This net reading will be the difference between the STOP reading and START reading. If KWH constants are the same for both meters, the two net numbers should agree with each other within 4% on less than 500 KWH and 1% on 500 KWH or more. This is a check to insure that recorded readings are correct and not a check on the accuracy of the meters. If the two net numbers do not agree and recorded readings are correct report it to the Division Meter Shop.

(2) When the recorder installation has only one meter (Westinghouse WR-31 recorder), compute the net reading for the kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

NOTE: If Step 4 was followed, skip Step 5 and go to Step 6.

5. If pointer is not in the "black" and the recorder clock indicates a different time than regular clock plus or minus 5 minutes, the following procedures should be followed:

A. Enter STOP date, Recorder TIME, AM or PM, and circle DAY of week on removed reading card.

B. Record correct time of day in space provided.

C. Read and record STOP readings from initiating meter. Read all dials.

D. Read and record STOP readings from revenue meter. Read all dials.

NOTE: Where only one meter is used (Residential Westinghouse WR-31 recorder):

(1) Read the STOP reading from the kilowatt-hour meter and record in the INITIATING METER section of the reading card.

(2) Enter the word SAME beside the words REVENUE METER on the reading card.

E. Turn tape advance 5 full turns in direction of arrow. Press the back edge of cartridge toward the tape advance knob (Capstan knob) and lift cartridge away from locking posts. Remove from recorder.

F. Set the recorder time before inserting cartridge. The recorder time may be set simply by turning the interval knob. The interval pointer should be set on zero when hour hand is moved. With interval pointer set on zero, the hour pointer should be set on the hour and the remaining portion set using the interval knob in order to maintain synchronism of the two hands.

G. Inspect the tape guide, recorder head and bias magnet for cleanliness. Use a chammy cloth dampened with magnetic tape head cleaner and wipe gently until clean.

H. Insert the new tape cartridge into recorder. Turn tape advance 5 full turns in direction of arrow.

I. On new reading card write the new tape cartridge serial number in proper space. Record the STOP readings for revenue and initiating meters as START readings on new card. Record START date, Recorder TIME, AM or PM, and circle DAY of week. NOTE: Recorder TIME must be the recorder clock time when the new tape cartridge was installed in the recorder. Check card to insure all data has been recorded, and sign card on the back in space provided. Fold reading card and insert in clips on tape cartridge.

J. Compute net readings:

(1) When the recorder installation has two meters (Westinghouse WR-2C recorder with revenue meter and initiating meter), compute the net readings for revenue and initiating meters on removed reading card. This net reading will be the difference between the STOP reading and START reading. If KWH constants are the same for both meters, the two net numbers should agree with each other within 4% on less than 500 KWH and 1% on 500 KWH or more. This is a check to insure that recorded readings are correct and not a check on the accuracy of the meters. If the two net numbers do not agree and recorded readings are correct report it to the Division Meter Shop.

(2) When the recorder installation has only one meter (Westinghouse WR-31 recorder), compute the net reading for kilowatt-hour meter on removed reading card. This net reading will be the difference between the STOP reading and START reading.

K. A complete investigation should be made to determine when power interruption occurred and how long it lasted. Record information in spaces 5A, 6A, 7A, 8A, and 9A as needed.

L. Check with Area Office to see what information is available on the power interruption. Attach a note to the tape cartridge giving all details on the interruption that are available.

6. Close door to recorder and lock. Lock should be placed on upper latch.

7. Sign removed reading card on the back in space provided and place it under the spring clips on the removed tape. Return tape with card to Area Office.

8. Report any unusual or abnormal conditions to Division Meter Shop.

9. Make a notation on the back of the removed reading card describing the unusual or abnormal condition and that the Division Meter Shop has been notified.

PROCEDURE FOR PROCESSING RECORDED MAGNETIC TAPES AND READING CARDS

When the recorded magnetic tapes have been changed and returned to the office, tapes should be processed as soon as possible, but not later than within five working days. The following processing procedure should be followed:

1. Open the cardboard box containing the magnetic tape. Remove the tape from the plastic cover. A folded reading card should be under the spring clips on the tape cartridges or in the plastic box in the case of a cassette.

2. Remove the card from the clips or the box. Verify the tape serial number on the reading card with the one on the magnetic tape to be sure they are identical. If they are identical, proceed to step 3. If they are not identical, do not change the number on the card but investigate to determine why the numbers are different and initiate corrective action as necessary. NOTE: The reading card may have been placed with the wrong tape and a check of the other tapes changed during this changeout may reveal tape and reading card mismatch. Also, the person changing the tape may have removed and reinstalled the same tape. If this is the case, have the tape changed immediately and note on the reading card what has occurred.

3. Compare the card with the corresponding one in the MASTER set. Make sure the recorder serial number, name, identification number, account number, recorder and meter constants are the same. (The MASTER cards are kept up to date by letter from the Rates and Service Practices Department when changes are made.)

4. Check the subtractions and constant applications for both the revenue meter and the initiating meter. The total KWH line should be completely filled out. The Meter Lab fills in total pulses.

5. Make sure that the STOP and START dates, DAY of week and TIMES are shown. Be sure to check AM and PM for clearly marked or circled time. Check to see that the day of week is circled also. If the date the tape was changed and the circled day of week are the same day, proceed to Step 6. If they do not agree, investigate to determine which is incorrect and make correction on reading card.

6. If a power interruption is indicated, make sure dates and times are shown. List each power outage date and time indicating AM or PM by circle or proper markings, and show total time of outage or outages. If no power outage information is available, state this in the power outage report. This is very important for Sangamo cassettes since these units don't have battery carryover.

7. Make sure that a recorded magnetic tape is on hand for every reading card in the MASTER set that is still active. Return any unused blank tapes and note why tape is blank on reading card.

8. Make sure all signatures on the back of card are signed. Person who verified data on reading card should sign the card on the back and indicate the date the data was verified. Under the remarks column on the back, list any unusual circumstances or information such as account is disconnected or idle account, etc.

9. Refold the reading card and place it back under the spring clips on the side of the cartridge or, in the case of a cassette, in the plastic box. Make sure it is held securely. This is the only identification we have for this magnetic tape.

10. Place the cartridge or cassette in the plastic cover and place in the cardboard box and put the top on it. Put a piece of cellophane tape on two edges to keep the top in place. NOTE: Do not use tape excessively as this will damage the boxes when cellophane tape is removed.

11. Stick the pre-addressed self-sticking label, which reads - To: Rate Department, RALEIGH, on top of each cardboard box.

12. Place the recorded magnetic tapes in the next meter can being shipped to Raleigh. If space is not available, some of the tapes can be held for shipment the following day.

Please EXERCISE EXTREME CAUTION in handling these magnetic tapes and reading cards. Each tape and the information recorded on it represent a substantial investment. Improper handling can easily render the magnetic tape and information worthless.

A sufficient quantity of blank magnetic tapes will be supplied before time for changing next month. Make sure blank magnetic tapes do not get mixed with recorded magnetic tapes.

If you have any questions, call the Rates and Service Practices Department in Raleigh.

CP&L
Carolina Power & Light Company

April 6, 1977

ALL DISTRICT AND AREA MANAGERS

Re: Load Research Project 1976-77

Gentlemen:

The next scheduled change of magnetic tapes on the load research customers is April 14 and 15, 1977. The required tape cartridges for this scheduled change are being sent each day as space is available in the meter cans. If you have not received the required number of tapes by April 13, 1977, please notify this office.

Our analysis of recent tape change problems indicates that the following areas should be brought to the attention of those who change the tapes:

1. Cleaning - The magnetic tape head cleaner (available in the warehouse) should be used with chammy skin to thoroughly clean the recorder head, tape guides, etc. at each tape change.

2. Many reading cards indicate that the tape change-out was done in one minute or less which is not enough time to thoroughly inspect and clean the recorder.

3. Personnel who are changing the tapes should verify their watch time, the day of the week and day of the month before going out to change the tapes as wrong time/date entries are causing some tape problems. The "Load Research Tape Installation Procedures" (Rev. 5/76) explain the actions to be taken if watch time and recorder time do not agree within 5 minutes. Note: Attached is a sketch of common time dial problems that may be encountered.

4. For the Sangamo and Duncan recorders, care must be taken <u>not</u> to advance the tape when the recording head is in contact with the tape.

5. Any unusual condition, i.e. grading noise, tape spilled out or damaged, etc., should be reported to the appropriate Meter Division personnel.

Additionally, office personnel who prepare and check the reading cards should be sure that: (1) the reading card and data entries are completely legible, especially where the reading card has been copied, (2) if the recorder clock time is off from the actual time by 5 minutes or more, the applicable power outage information or a remark that no power outage information was available should be entered in the power interruption section of the reading card.

It is hoped that these suggestions will help to decrease the tape problems that we have been encountering and, therefore, increase our data reliability.

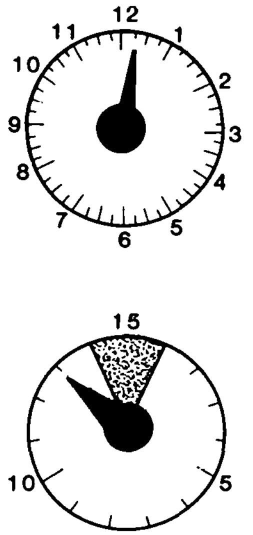
If you have any questions concerning this scheduled tape change or the above suggestions, please feel free to call me.

Thank you for your cooperation in this vital project.

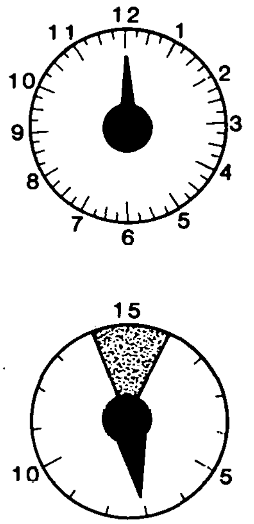
Yours truly,

Supervising Analyst
Load Research Unit
Rates & Service Practices Dept.

Attachment



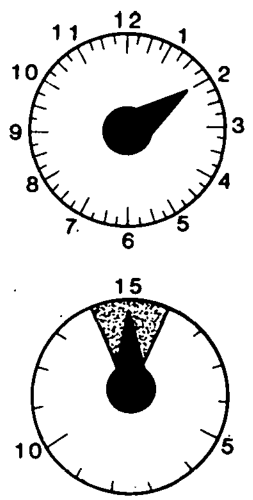
This dial often would be read as 12:15 + 13 for a total of 12:28. In this case, the translation would be rejected for being one time pulse short. The actual reading should be 12:13. If the person changing the tape had checked his watch, he would have noticed a time difference of 15 minutes.



This time dial is obviously not synchronized. While the tape is out of the recorder, the operator should:

1 - Turn the 15-minute dial through 1 rotation and listen for a click as the pointer passes the 15 mark.

2 - Set the 15-minute dial on 15 and turn the hour dial to an hour mark near the hour desired. Then set the exact time by turning just the 15-minute dial.



Changing the tape on this recorder would probably result in a rejected report. The 15-minute pointer drives a small cam which records a time pulse on the tape just as the pointer passes the 15 mark. If a click is heard when the pointer is indicating any other time, the knob has slipped on the shaft and the Division Meter Shop should be notified.

APPENDIX E

EDITING DATA POINTS

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EDITING DATA POINTS

This appendix discusses procedures for estimating customer demand levels for those time intervals where data are missing on the customer's recording tape. Several alternative ways of addressing this problem will be discussed, involving varying degrees of sophistication. These are only illustrations and it is not necessary that utilities fabricate surrogate data.

LINEAR INTERPOLATION

If the intervals with missing data are short -- e.g., 15-min omissions (see Figure E.1) -- one might safely interpolate the demands immediately preceding and following the missing observation to obtain a fairly reliable estimate. For example, if demand at 12:45 is missing, one may linearly interpolate demand at 12:30 (say 100) and demand at 1:00 (say 120) to obtain an estimate for 12:45 (in this case, 110). This procedure is not appealing for longer intervals.

USING TOTAL KILOWATT-HOUR DATA

If the tape is missing only one data point and the analyst feels confident that the total kilowatt-hour reading on the meter is correct, he may

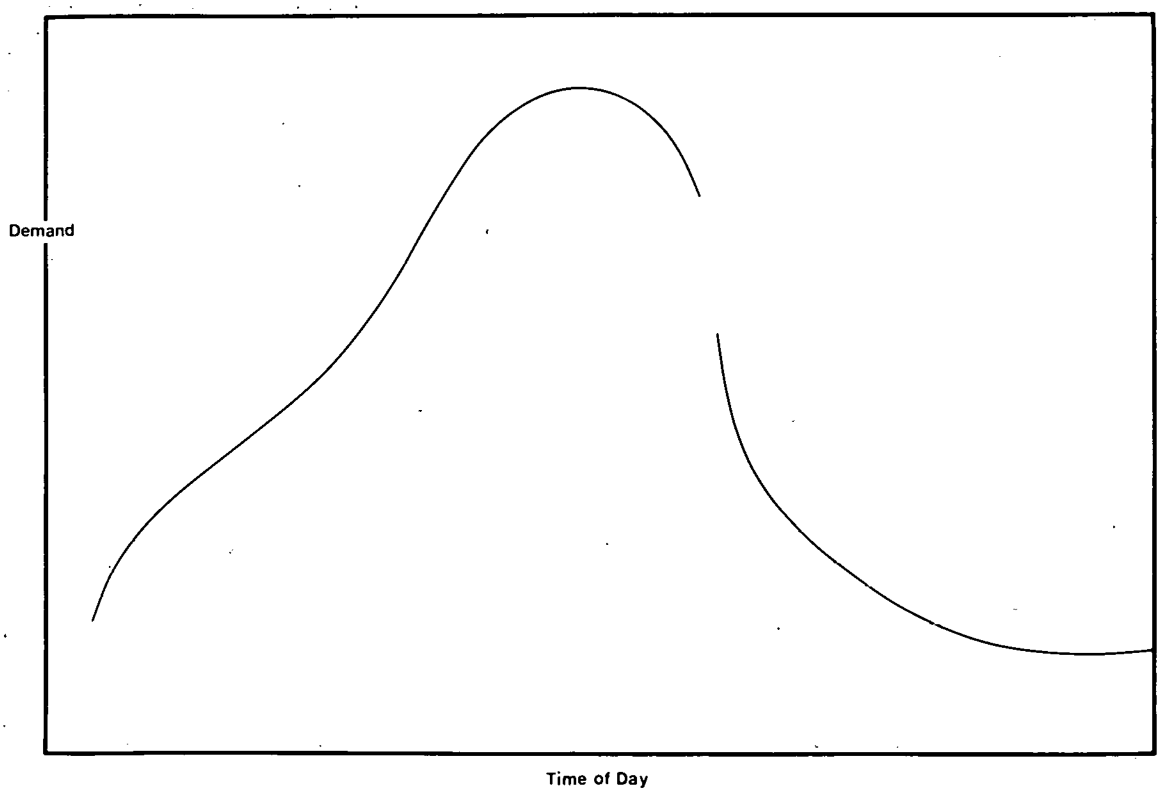

Fig. E.1 Short Missing Interval for Time-of-Day Demand subtract tape kilowatt-hours from meter kilowatt-hours to estimate the missing demand level. For example, if tape kilowatt-hours total 980 while meter kilowatt-hours are 1000, one missing interval can be patched with 20. However, this relies on the meter's total kilowatt-hour reading; if this reading is wrong, this procedure will not provide accurate estimates.

LONGER MISSING INTERVALS

If several adjacent intervals on a tape are missing demand data, the problem grows more complex (see Figure E.2). Linear interpolation is not appealing since the demands might not in fact follow a linear pattern over time (see Figure E.3). If one subtracts tape kilowatt-hours from meter kilowatt-hours, there is still no way of allocating this difference to the several missing intervals.

Perhaps the best way of patching long missing demand intervals is to interpolate the missing demands from a model load curve. For example, suppose the researcher encounters missing data between 1:00 and 4:00 (see Figure E.4a). These points can be interpolated from a model curve (see Figure E.4b). To do this, the ratios R may be calculated:

R(1:00) = demand A(1:00)/demand B(1:00)

R(4:00) = demand A(4:00)/demand B(4:00)

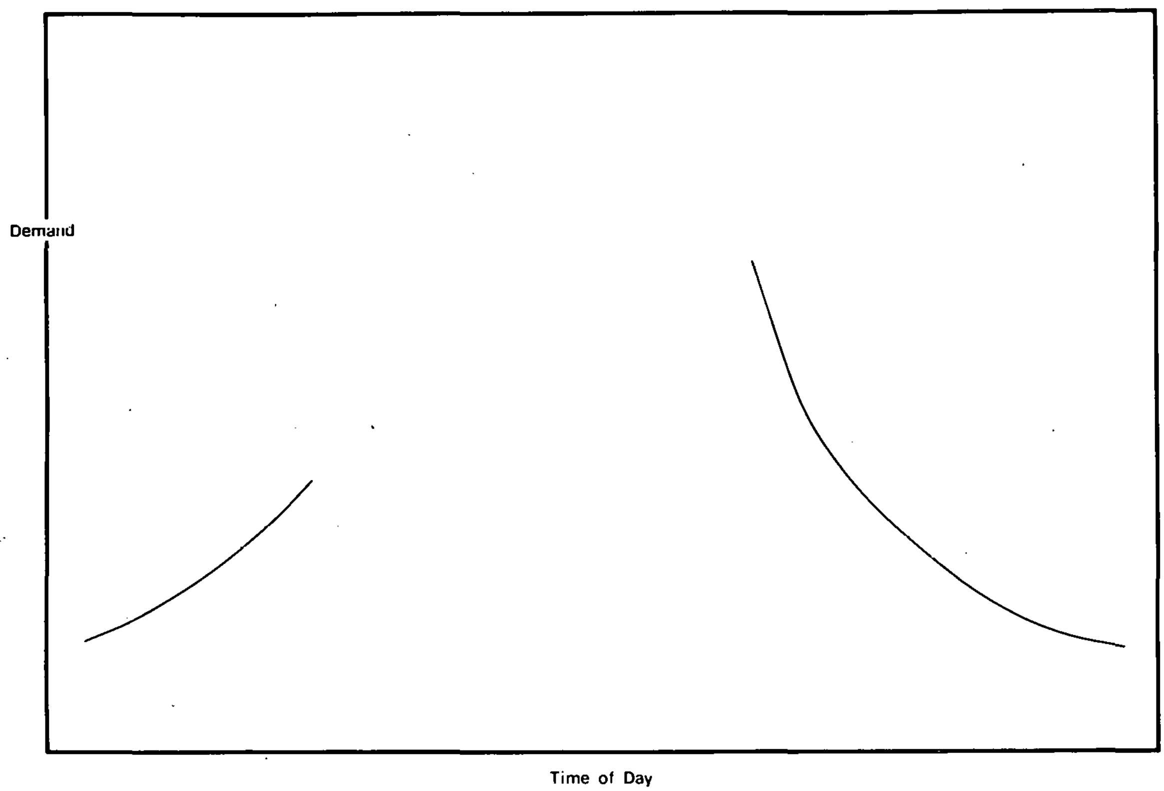

Fig. E.2 Longer Missing Interval for Time-of-Day Demand

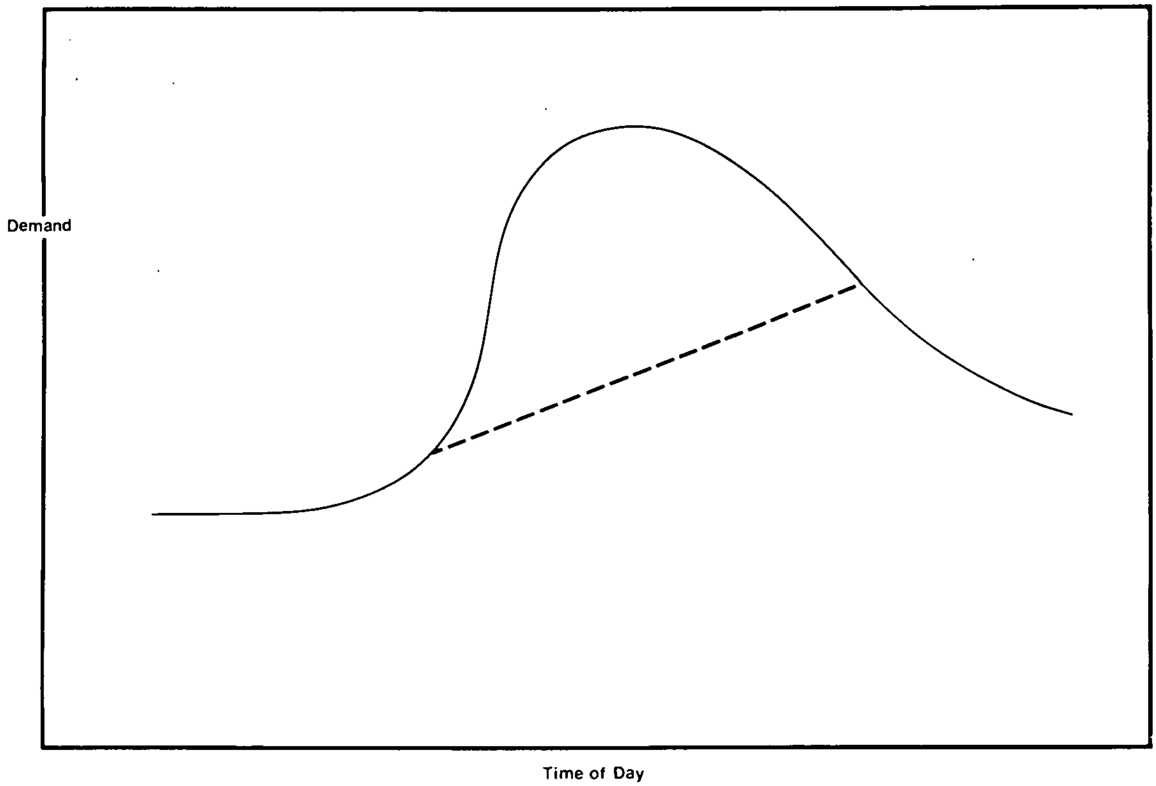

Fig. E.3 Linearly Interpolated (dashed line) and Actual (solid line) Demand by Time of Day

These R values may be interpolated to obtain intermediate values at 1:15, 1:30, ..., 3:45. Upon multiplying the interpolated values by actual demand B for the respective interval, the analyst obtains a fairly good estimation of demand A. That is, for 3:30, estimated demand A(3:30) = interpolated R(3:30) x actual demand B(3:30).

The fundamental problem with this interpolation technique involves the choice of a model demand curve B with which one may interpolate A. Essentially, the model demand curve B should be a curve expected to resemble the demand curve A. This choice has no immediately obvious solution and involves as much art as science.

Loads comprise weather-insensitive (base) and weather-sensitive components. Since weather patterns differ across days, it seems logical that one should choose a model curve from the same day as the missing data. If this be the case, one would use another customer's demand curve to interpolate a particular customer's missing data, taking care to choose a curve from the same day.

However, base usage patterns, which have less to do with weather, differ much more across customers than they do across days. Since base patterns can differ substantially among customers, it then seems logical that one should use a model curve from the same customer.

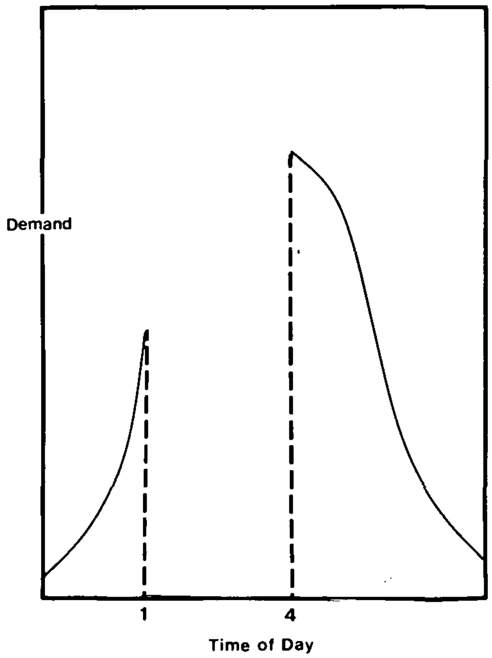

Fig. E.4a Missing Demand Data

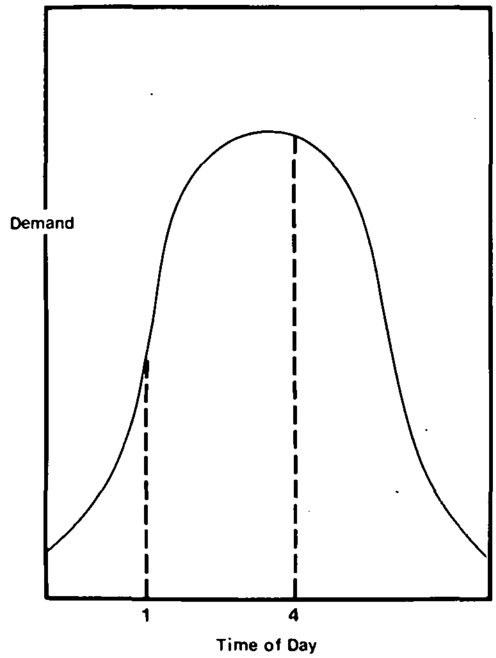

Fig. E.4b Model Load Curve

Two opposite procedures then have been presented. For temperate days having no weather discomfort, the choice is clear -- interpolate a customer's missing data with his load curve from another temperate day. On very hot and cold days, the problem is considerably more complicated; the weather-sensitive portion of the missing demands should be interpolated from "same day-different customer" data while the base component of missing demands should be interpolated from "same customer-different day" data. Two possibilities arise. One might simply decide which component, base or weather-sensitive, is greater and select the appropriate technique; most often, the base load will exceed the weather-sensitive load.

Alternatively, one may be more selective about the model curve. For example, if the weather-sensitive component is sizable, one may choose as a model curve the same customer's load curve from another day having similar weather conditions (at least one will probably exist). By contrast, one may choose as a model curve a "same-day" load curve from another customer who is similar to the "missing" customer; customers can be compared from days where all customer demand patterns are available. The benefit of this "similar-day" or "similar-customer" selection process entails its greater theoretical precision. The disadvantage is that few model curves may prove to be available with this approach.

Should one wish to ensure that tape total kilowatt-hours sum to the billing meter reading (assuming the latter is reliable enough), one might resolve the problem of long missing intervals by first estimating with appropriate procedures the missing data and then adjusting each amount proportionally to assure that total kilowatt-hours equal billing meter kilowatt-hours. One must be cautious since the resulting demand estimates might not follow a credible pattern (see Figure E.5).

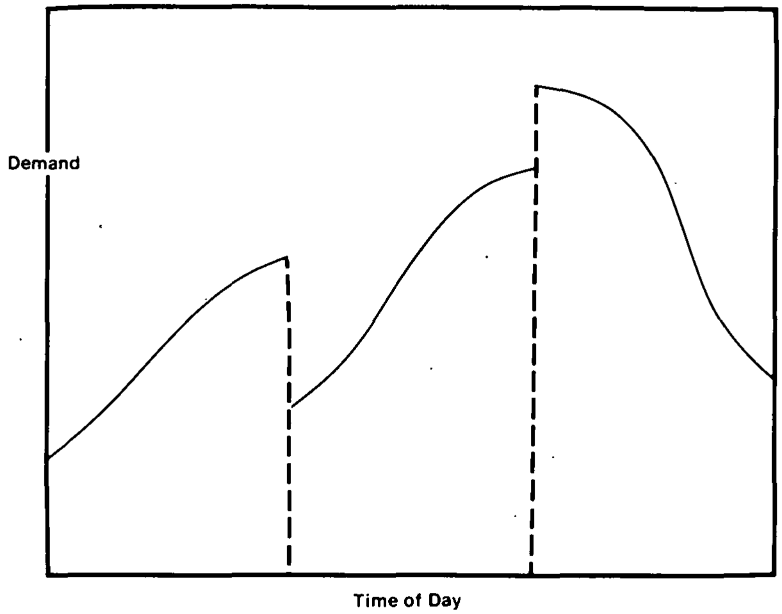

Fig. E.5 Dangers of Constraining Interpolated Loads

As with other aspects of load research, there are no immediate or obvious answers to the problems of patching missing data points. Any solution depends on the length of the missing demand intervals, the reliability of billing meter readings, the degree of weather sensitivity, the degree of similarity across days and customers, the availability of data from similar customers, and the availability of data from similar days.

INCREMENTAL INTERPOLATION

Another method of interpolating demand data over lengthy time intervals is based on the observed differences in customer demand between two curves. Suppose, as before, demand data are missing for customer A between 1 p.m. and 4 p.m. A model curve can be chosen as before: e.g., the same customer on a different day or a different customer on the same day. This customer will be designated customer B.

At the endpoints of the missing data interval, the differences between the two curves can be calculated:

$$I_1 = L_1^A - L_1^B$$

$$I_4 = L_4^A - L_4^B$$

where:

I_i = differences between demand by customers A and B at hour i,

L_i^A = demand by customer A at hour i, and

L_i^B = demand by customer B at hour i.

The values of I_1 and I_4 may be linearly interpolated to obtain I_i $(1 < i < 4)$ for each hour i in the missing data interval. From here, L_i^A may be constructed:

$$L_i^A = L_i^B + I_i$$

Table E.1 illustrates this procedure.

Table E.1 Illustration of Interpolation of Increments

Hour	Customer A	Customer B	Interpolated Difference	Constructed Demand
1:00	200	188	12	200
1:15		194	14	208
1:30		200	16	216
1:45		208	18	226
2:00		216	20	236
2:15		225	22	247
2:30		234	24	258
2:45		242	26	268
3:00		250	28	278
3:15		258	30	288
3:30		270	32	302
3:45		275	34	309
4:00	300	264	36	300

APPENDIX F

NERA* SURVEY OF LOAD RESEARCH PROGRAMS AT SELECTED UTILITIES: QUESTIONS AND RESPONSES

*National Economic Research Associates, Inc.

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QUESTIONNAIRE

I. BACKGROUND

A. GENERAL INFORMATION

1. Company name
2. Address
3. Telephone number
4. Service
   a. Number of customers serviced
   b. Square miles of territory serviced
   c. Characteristics of service territory (i.e., residential, commercial, industrial mix)
5. Annual sales of electric energy (in $ and MW)
6. System capability
7. System reliability
8. Maintenance scheduling
9. System peak:
   a. Season
   b. Month
   c. Time
   d. Sectoral peaks
   e. Peak of residential/commercial load
10. Have you ever done any time-of-day pricing experiments?
11. What amount of the peak is weather sensitive?

B. LOAD RESEARCH PROGRAM

1. When was the load research program initiated?
2. Why was the program initiated?
3. Where was the program initiated (i.e., bottom up or top down).
4. List the names and positions of people instrumental in designing the program.
5. Give a brief description of the load research design.
6. Have any drastic changes been made since its inception? Explain.
7. In what areas have minor changes been made?
8. In general, how will the current program be affected by the requirements of PURPA?

II. LOAD RESEARCH DESIGN

A. DEFINITIONS

1. Define the purpose and objectives of the load research program.
2. Define the "universe" under study.

B. SAMPLE DESIGN

1. What technique of sampling is used?
   a. If stratified sampling is used, what is the basis for stratification?
   b. If systematic sampling of the universe is used, describe the "system" or method used.
   c. If any combination of techniques is used, explain.

2. Does the sample purport to be representative of all customers or of a particular class of customers?

3. Is a specific formula or equation used for statistical purposes?
   a. How large is the sample size?
   b. What level of confidence is obtained?
   c. What would you estimate the sampling error or confidence interval to be?

4. Are you satisfied with your sampling technique? Why or why not?

5. How does PURPA affect your sample design?

C. METERING

1. Are customers required to complete questionnaires?

2. Are demographics important? Is income monitored?

3. What sort of records are kept on each participating customer (e.g., metering cards)? What information is contained in these records?

4. What type of meter is used?
   a. Is more than one type used?
   b. What are the brand names of the meters used?

5. Do your meters reflect the latest technology? If not, why not?

6. How much does a meter cost?

7. Where are the meters installed?
   a. Large vs. small customers. Are apartments treated differently from houses?
   b. Why do you meter what you meter (e.g., restaurants)?
   c. How do you perceive your needs to be similar or different from others?

8. LILCO stressed the fact that most meters are installed outside the house. What percentage of meters do you install outside as opposed to inside a dwelling unit? Why do you install meters outside (e.g., easier to read, less resistance)?

9. Am I correct in assuming that individual versus master metering depends on the nature of the study?

10. a. What kind of load management are you comtemplating?
    b. What kinds of activities do you pursue to increase load factor?

D. DATA REQUIREMENTS

1. What is the demand interval used in recording energy consumption?

2. What is the approximate length of the study?

3. How often are metering tapes collected?

4. Are time-of-day weather conditions recorded with the meter-reading?

5. How do you account for outages in the load?

6. LILCO claims that 15% of its tapes each month are deemed useless because of human error or mechanical malfunction.
   a. What percentage of your tapes become useless?
   b. When is a sample member/or tape rejected as invalid?
   c. Is the original sample large enough to provide alternate sample members? (LILCO's sample is three times larger than that actually needed).

7. Are samples rotated or alternated to reflect changes in population and load characteristics? (I.e., what happens if a participant moves out of the area?) How often?

8. Are there any problems with tabulation or documentation of data and results?

9. PURPA
   a. Are PURPA data requirements more stringent than your own?
   b. What kinds of requirements are set by your Public Utility Commission?
   c. What changes must you make in this area to comply with PURPA regulations?

E. SOFTWARE SYSTEM

1. How sophisticated is your software?

2. How long did it take to develop the software?

3. Who developed it?

4. Is it documented so that a new operator or programmer will be able to tackle problems that may arise?

5. What kind of computer is used?
   a. Brand?
   b. In-house or time-sharing?

6. Who controls the translator?

7. Is data collected for uses other than load research?

8. What is the approximate down-time on the computer? Is maintenance a major problem?

F. MISCELLANEOUS

1. Is a specific schedule or time table adhered to?

2. What reporting format is used?

3. What would you estimate the total cost of a load research program to be?
    a. Are the costs already prohibitive?
    b. How will PURPA affect the current cost structure?

III. THE HUMAN FACTOR

A. CUSTOMERS

1. What is the general attitude of customers toward load research? Does that attitude differ by class of customer (residential, commercial, industrial)?
2. Is customer cooperation a problem?
3. How do you overcome resistance?
4. Are incentives offered? If so, what kind?

B. LABOR

1. Does labor turnover affect the accuracy of data and results?
2. Does a conservative view hamper the success or progress of the load research program?
3. Does the load research department work closely with the metering department?
4. Comment on interdepartment cooperation?

IV. PURPA

1. What start-up problems did you encounter?
2. If you had to do it again, what would you do differently?
3. How can public utilities just getting into load research avoid some of these problems?
4. What immediate effects do you suspect PURPA will have on the smaller public utilities? In the long-term?

SUPPLEMENTAL INTERVIEW QUESTIONS

1. List new objectives of load research.
2. Define universe: residential, commercial, industrial. Are others studied as group (e.g., electric water heating)?
3. What are the strata used? When was each group stratified?
4. How do you estimate strata variance?
5. How do you gauge the representativeness of a sample (e.g., chi-square test)?
6. Do you ever allocate a sample across strata for the purpose of estimating efficient regression coefficients?
7. Are samples alternated? How? Rotated?
8. Do customers fill out questionnaires? How is data on population gathered?
9. Who is systematically excluded from samples?
10. Brand of recorder used - Why? Percent of recorders with battery carry-over?
11. Are cartridge tapes or 2-channel cassettes used?
12. Who installs meter?
13. Where are meters installed? If outdoors, what precautions are taken?
14. Do you bulk-meter? From transformer?
15. Do you worry about anything other than kilowatts, e.g., power factor?
16. Are 30-day tapes used? (Or 45-, 60-, or 90-day tapes?)
17. How much historical data is stored?
18. Is analysis on 15-minute basis?
19. What are you required to do by state power commission?

Table F.1 Matrix of Company Responses to Questionnaire

Question	CP&L	LILCO	SoCal Ed
Name, Address, Telephone number	Carolina Power and Light Co. 411 Fayetteville Street P.O. Box 1551 Raleigh, NC 27602 (919) 836-6111	Long Island Lighting Co. 250 Old Country Road Mineola, NY (516) 228-2890	Southern California Edison Co. 2244 Walnut Grove Avenue P.O. Box 800 Rosemead, CA 91770 (213) 572-1212
Number of customers/ Area of service territory/ Characteristics of service territory	710,000 customers/30,000 sq. miles/NC-coastal, Piedmont: SC-Piedmont/33% residential, 67% commercial and industrial (agricultural/manufacturing activity)	890,000 customers/1,230 sq. miles/Predominantly residential, some significant commercial and industrial revenues (Suffolk - leading agricultural county)	3 million customers/50,000 sq. miles/Central and southern California except LA & San Diego; every type of weather
Annual sales of electric energy (1978): $ MW	$903 million approx. 28,000 MW	$740 million 13,237 MW	$3.5 billion approx. 57,000 MW
System capability	7,800 MW	3,842 MW	14,703 MW
System peak: season, month, time	Dual peak--recent leap-frogging: summer, Aug. 5-6 pm; winter, Jan. 8-9 am	Summer - July or Aug. weekday 6 pm (could be changing)	Summer June-Sept.
Time-of-day pricing	Yes	Yes (216 cust) 750 kW and commercial/industrial (Feb 1, 1977) res. (Jan 1, 1980) 45,000 kW (1,100)	Yes
Program initiated in By For	1969 Rate dept. Cost-of-service and rate design	1964 Economic research Dept. Cost-of-service, forecasting	1970 Rate dept. Cost-of-service, cost allocation
Major/minor changes	Reduced number of rate schedules, reduced size of some samples	Sampling technique changed in 1976	Samples revamped in 1975 and 1979. Translation by metering dept.
General effect of PURPA on current program	Class by class may exceed requirement. Suggested fixed standard.	--	Concern about load research data requirements, a few weak sample groups
Define universe	----------Depends on Individual Project----------		

Table F.1 (Cont'd)

Question	CP&L	LILCO	SoCal Ed
Customer classes	Residential Small general service General service Large general service (over 1000 kW)	Residential Commercial Commercial-industrial 50-800 kW 800-1600 kW over 1600 kW	Domestic rate class/lighting and small power/large power/very large power/agriculture and pumping/resale
Sampling technique	Stratified random sample (Higgins) Neyman optimal allocation: weight from bill frequency; borrowed method of variance; in-house program to select sample from population	Residential/small commercial classes stratified by energy, large commercial/industrial stratified by demand. Stratified in 1976 for more accurate data, reduce error, cut number of meters required	Random list for load management Time-of-use samples systematically drawn. Systematic preferred.
Sample size	715 recorders--doesn't allow testing of all classes in test year so stagger every 2 years	600 recorders	4,000 meters
Is sample large enough?	Yes - primary selection plus 4 alternates from same area or similar kWh usage	Yes - primary selection plus 2 back-up samples. Without replacement, sample is 3 times as large as needed	Yes
Are samples rotated or alternated? How often?	Yes	Samples are rolled. Recent sample in 3 years.	No
Confidence level	95%	95% Future samples will be designed to exceed requirements	95% Within PURPA standard for level of accuracy. Worst sample is $\pm 17\%$ error at 90% confidence
Sampling error	10%	5%	10%
Do customers complete questionnaires?	Yes	No	Yes
Are demographics important?	Yes	Some	Yes
Type of records	Master sheet for survey work	Meter card	Original questionnaire, on tape to be used in data base.

Table F.1 (Cont'd)

Question	CP&L	LILCO	SoCal Ed
Information contained in records	Account number, ID number, SIC. Customer name and address. Physical description of dwelling unit. Major electric load meter mounting. Type and age of residence. Head of household.	--	Demographic information. Appliance information. Records filed on original questionnaire.
Recording meter (type/brand/cost)	($7000) 4 cartridge Westinghouse: WR-2C w/battery carryover WR-31 slim line w/bc Duncan cassette w/bc	($600) Westinghouse cartridge	($400-700) Westinghouse cartridge Duncan, GE, Sangamo 90% have battery carry-over
Does load research metering equipment reflect latest technology?	WR-31	Two-way communication systems. Many being tested/investigated.	Computer, mini-computer. Move toward microprocessor.
Where are meters installed? Why?	At meter base; sometimes remote. Not pole mount. Churches as group by SIC code.	Pole top. Outside dwellings.	80% from meter socket. None pole-top, some fence-top.
Demand interval	15 min. Analysis based on integrated 60-min demand interval.	Mostly 15 min. Some 30 min.	15 min. 5 min for A/C study.
Frequency of tape collection	Monthly. Tapes changed on 5-6th day of every month. Use 30-day tape to identify malfunction as soon as possible.	30-day tapes. Staggered.	Monthly. About 3 months, staggered to spread work load/tapes changed by testmen rather than meter readers as in past.
Length of study	Demand metered for 12 continuous months vs. 3 summer months, plus 3 winter months.	Annual	Continuous. Annual report-move toward monthly. Load management depends on study.
Are time-of-day weather data collected?	No (no normalization)	Data normalized for weather conditions	Yes
Percentages of tapes rejected	25% don't meet acceptable level, 3-10% loss od data. Try for 100% accuracy of present sample.	15% per month	1.5% degraded; 3% assoc. w/malfunction; 5-7% have some form of loss; 25-30% flagged for analyst's attention

Table F.1 (Cont'd)

Question	CP&L	LILCO	SoCal Ed
When is tape rejected?	1-2 interval discrepancies not explainable. Reject tape if 3 interval differences cannot be resolved.	Reject tape w/more than 1-hour time difference	Most data can be "saved"
Translator	WLT-40, upgraded ($132,000)	WLT-40 ($80-100,000)	HP MX21 mini-computer, Westinghouse system ($250,000)
Translator controlled by	Translation at user-level (rate department)	Metering department	Metering department
Editing procedure	Try to "save" as much data as possible. 6-12 months historical data used to match intervals.	--	Detailed tabulation of validation procedures and checks. 33% of tapes are checked. Editing function at front-end rather than at end-use. Validation is strong point of system.
Who developed software?	Westinghouse system with in-house input. Analysis package: data from master file analysis designed around translator system.	More than 90% writted by LILCO load research team	Westinghouse-packaged system tailored for SoCal Ed. Some SoCal Ed developed programs.
Documentation	Yes. Skilled programmer in-house capability.	Problem when person who developed program left the company	Fully documented
Computer	Hewlett-Packard computer. Westinghouse system.	IBM 30-33	IBM 370
Reporting format	Acceptable data are put on microfiche	Group divide--data by class etc., in different formats; in one report	Monthly plus summary
Costs	Total: $250,000-500,000 Translation: $100,000-150,000	--	--
Timetable	Wait 2 months for complete calendar data reminders to change tapes. 3-6 weeks of processing. Total about 10 weeks.	--	5 weeks to get data from start to finish for use in load study
Customer attitude	Good; matter of community pride	Fair, sometimes suspicion arcused	Ok-low rejection rate (less than 10%) (no feedback about attitudes)

Table F.1 (Cont'd)

Question	CP&L	LILCO	SoCal Ed
Customer cooperation	Good--4-6% refusals. Customer service/PR-trained in power of persuasion.	Fair to good	Good. In special studies cooperate because of energy consciousness.
Are incentives offered?	No	Yes	No. Depends on study. Not on load study.
Does labor turnover affect load research program/projects?	No--excellent training programs at all levels of load research project.	Yes--dramatically, especially in metering and software departments.	In data-processing department Turnover was problem. Translation/analysis no longer handled there.
Interdepartment cooperation	Good relationship between metering and load research departments	Good. Centrally directed flow of data. Communication vital.	Excellent between metering and load research department. Good communication throughout company. All levels of management informed. High-level-management involvement.
How can inexperienced companies avoid problems you encountered?	Talk to other firms that have developed load research programs. LR task force should have reps from rate, computer, customer service, meter departments, public relations consultant. Anticipate problems and be prepared to handle them. Don't get locked into one manufacturer's equipment.	--	Small utility should use translator w/mini-computer since they won't be putting load mgt, billing, etc., on same system. Beginners cannot start simple. 800-900 meters needed no matter what size population. Educate themselves on state of the art. PUC would have more impact on utilities than PURPA but costly to comply with federal regulation.
If you had to develop a load research program all over again, what would you do differently?	Different procedures. Need battery-carry-over for power outages. Avoid use of cassette recorders--tapes prone to malfunction. System should give maximum flexibility to account for progress, technology, etc. Learn a lot in first 3 years. Other have benefit of more published material.	On-line editing system. Getting new equipment w/time sharing option, software not available.	Select samples and allocate meters differently. More sophisticated stratification. Design program around solid state data acquisition system (real time), rather than magnetic recorder. Fully automated monthly load study in all respects. Flexibility to allow for peak load day studies after peak day had occurred (next day if real-time). Base weighting factor on accumulated 12 months (to date) frequency distribution, allow factors to vary monthly.

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