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MASTER

Discussion Series on PURPA Related Topics*

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METERING

BILLING

**INFORMATION
TO CUSTOMERS**

**LOAD
MANAGEMENT**

**MASTER
METERING**

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Prepared for:
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August 1980

Master

Prepared by:
James I. Sturgeon
City Utilities of Springfield, Missouri
Springfield, Missouri
Under Contract No. FC01-77ZZ00335

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METERING

BILLING

**INFORMATION
TO CUSTOMERS**

**LOAD
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**MASTER
METERING**

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ACKNOWLEDGEMENTS

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This report was prepared under a subcontract from City Utilities of Springfield, Missouri. The work is part of the cooperative agreement between City Utilities and the United States Department of Energy. The principal author of the report is James I. Sturgeon of the University of Missouri-Kansas City and Mid-America Economic Research Associates, Inc. He would like to acknowledge the assistance of all of the members of the project staff and in particular Robert E. Sanders. Also, Ms. Cathleen E. Meyers of City Utilities of Springfield was very helpful in reviewing earlier drafts and outlines and in seeing that administrative details involving the work were promptly and expertly completed.

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The statements, findings and conclusions are the responsibility of the author and do not necessarily reflect or state those of the Department of Energy, City Utilities of Springfield, or those who have contributed data to this report.

ABSTRACT

Time-differentiated metering of electricity consumption and demand is required in both rate-structure experimentation and the implementation of most time-of-use (TOU) rate designs.

Time-differentiated metering takes three major forms: multi-register watthour meters, magnetic tape recording meters, and remote automatic meter reading systems. The majority of projects selected magnetic tape meters for their flexibility with respect to rate structure, load-survey capabilities, and ready availability. The small-scale, experimental nature of the projects reduced the significance of the large difference in per unit cost and operational/maintenance complexity between this form of metering and the multi-register form. Magnetic tape meters are not likely candidates for system-wide implementation of time-differentiated metering. Automatic remote meter reading systems were not adequately available during the project years; those projects attempting to use these were unable to bring them to full operational status before project termination, due to the many problems of design, quality control, and equipment acquisition encountered.

Delays in acquisition and problems of quality control also followed the selection of magnetic tape meters and multi-register meters by a number of the projects. Though less complex than automatic remote reading systems, these technologies are still new and more complex than standard watthour metering. Thus, both equipment vendors and utilities encountered numerous problems in getting properly functioning meters to the service entrances on time. A variety of factors contributed to installation delays, including unforeseen space limitations, incompatible wiring, problems of task organization, and customer reluctance.

Both multi-register and magnetic tape metering require a heavier maintenance commitment than single-dial metering, but magnetic tape equipment is by far the more problem-laden of the two. Its operational complexity greatly increases possibility of error while its functional complexity increases the likelihood of breakdown. Most projects experienced malfunction rates in magnetic tape meters that would be extremely serious in large-scale implementation. An important operational consideration in both forms of metering is dealing with power outages, which, in the absence of a carryover capacity, introduce unacceptable time-errors.

Adverse customer reaction to new metering equipment has much to do with a general unfamiliarity with its characteristics and purpose. Unless it is borne in mind that customers are unlikely to know much about metering of any kind, many of their responses to new equipment will be unanticipated, and can appear capricious and bizarre. Customers have valid aesthetic and privacy interests that must be taken into account in planning and executing the change from standard to time-differentiated metering equipment.

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THE DISCUSSION SERIES ON PURPA RELATED TOPICS

INTRODUCTION

The Discussion Series on PURPA Related Topics is composed of five volumes: Metering, Billing, Information to Customers, Load Management Techniques and Master Metering. These reports are based on twenty-five Demonstration and Implementation projects sponsored and directed during the past five years by the U.S. Department of Energy, Office of Utility Systems. Each of the topics bears directly on one or more of the federal standards contained in the Public Utilities Regulatory Policies Act of 1978 (PURPA). This volume, Metering, relates primarily to the Time-of-Day Rates standard, PURPA IB(d)3. Because the experiences related in this report deal, in part, with load research-type metering, this volume can also aid in the implementation of the Cost of Service Standard, PURPA IB(d)1, and Section 133 which deals with the gathering of Cost-of-Service data.

One goal of these reports is to describe how people in a variety of settings have dealt with the many practical issues in each topic area. Another is to highlight the lessons and summarize the experiences of the project participants. These reports do not stand as systems manuals or provide prescriptive guidelines on how to deal with these topics. Rather they offer an account for those charged with the responsibility of implementing PURPA requirements to learn from the insights and problems which occurred during the Rate Demonstration projects.

This series of reports will be useful to utility and regulatory people in judging the full scope of work related to these topics, anticipating problems and planning the spectrum of requisite activities.

CHAPTER :
ONE : INTRODUCTION
:

The DOE sponsored Electric Rate Demonstration Projects (Projects) were more than elasticity measurements, demand projections, usage figures, and statistical analyses. Behind each table and graph in the Project reports are experiences in planning and implementation of work which has been ongoing in each Project for several years. This inaugural report on metering looks at the many field experiences in the Projects dealing with demonstrating how customers respond to Time-of-Use (TOU) rates.

This volume is not an engineer's or economist's manual, but an account of field activities involving all aspects of meter selection and operation. The purpose here is to synthesize the experiences and highlight patterns and anomalies with specific examples. By so doing it is hoped that the uninitiated will have the opportunity to participate in the experiences of others before themselves engaging in work with time differentiated metering equipment.

A number of electric utilities and public service commissions will soon become involved for the first time in the implementation of the PURPA standard on Time-of-Day rates, IB(d)1; this report is primarily for their use. Information contained here, however, may also be useful to meter manufacturers and consultants. They will have the opportunity to assess Project accounts of field experiences, providing a viewpoint which may ultimately aid in design and the preparation of installation and operating procedures.

Large volumes of data, daily logs, field reports and other documentation from the Projects serve as a source of information for this report. Review of these files led to the basic design of the report. Follow-up interviews with Project personnel provided the detail and richness of first-hand experience.

Two general observations stand out in this report:

- In order to obtain useful data from non-single watthour

metering equipment, especially magnetic tape recorders, utility personnel needed to specify precisely their equipment requirements, exercise quality control on deliverables from vendors, purchase back-up units, and invest significant resources in maintaining the equipment.

- Effective use of metering alternatives required changing significantly the utilities' planning and operating patterns, and habits for metering. Where such adjustments were not made, utilities experienced inordinate difficulties in meter delivery and installation schedules, inappropriate or faulty new equipment, service entrance space and wiring problems, poor customer relations and lost data.

The chart which follows presents a synopsis of the metering experiences of the Projects. The chart is organized along the same lines as the main chapters of the report and lists the activities or experiences that are discussed in the report.

CHART 1

SYNOPSIS OF TOU METERING

CHAPTER :
TWO : METERING: AN OVERVIEW
:

INTRODUCTION

This chapter contains three main sections. First is a general discussion of some relationships among Time-of-Use (TOU) rates, metering, load research, and load management. This is a brief discussion and serves as an introduction to the next section, which discusses the planning done by some of the Projects in their selection of metering equipment. It reviews the performance and cost criteria used, and some of the pragmatic, institutional, and physical factors taken into account in reaching decisions on what kind of meters to acquire. The final section reviews the types, manufacturers, numbers, and costs of meters selected by each Project, to the extent these data could be obtained.

METERING AND TOU RATES

The electricity consumed at six o'clock in the morning is physically identical to that consumed at six o'clock in the evening, but in many electric utility systems these two quantities of electricity are produced by different means and at different cost. What this means is that physically electricity is identical, but economically it is not. At one time of day the utility may be meeting the demand of the system by operating only large, efficient "base load" generating plants, e.g., steam powered turbines. At another time, in order to meet the system demand, the utility may have to operate nearly all its generating equipment including relatively inefficient gas turbines or diesel generators. Electricity produced under the latter conditions is usually a more expensive commodity.¹

TOU pricing of electricity treats the physically identical electricity consumed by customers throughout the day (or week, or season) as two or more distinct commodities for sale at

¹An exception may be systems that use hydro-generated power during peak conditions.

different prices, prices determined not by their differential usefulness to the customer, but by their differential costs of production. Electricity cannot be stored after generation in bins, as it were, marked "cheaply produced," "less cheaply produced," "expensively produced," with suitable price tags attached. When electricity is being cheaply generated all the electricity available in the system is cheap; when demand is so great that the least efficient generators have been called upon, then all the electricity in the system is at its costliest. Most non-TOU rate structures require only the total number of kilowatt hours consumed by the customer throughout the billing period. TOU rate structures require separate records of electricity consumed at different times.

Time differentiation of electricity consumption can be accomplished with the same metering equipment as is currently used for non-TOU rate structures only if the periods used for this differentiation are no shorter than the shortest feasible time between meter readings. For example, it may be practical to establish a price difference between electricity consumed during one season of the year and that consumed during another without alternation of the metering equipment already in place throughout the system. In some utility systems seasonal variations in aggregate demand are significant, and thus better approximations to cost-based pricing can be achieved by implementing seasonal rate structures (PURPA IB(d)4). But in other utility systems the variation in demand over hours of the day is substantially greater than the variation in demand over seasons of the year, and so Time-of-Day (TOD) pricing would represent a closer approximation to cost-based pricing of electricity.

Implementation of TOD pricing in the residential sector will usually entail the replacement or augmentation of most existing metering equipment. The general requirement is a means to segregate the record of consumption without dispatching personnel to service entrances each time the rate changes (a virtual impossibility). Such means take two main forms:

1) equipment at the service entrance capable of identifying records of consumption according to time of day or 2) automatic meter reading systems capable of interrogating each meter at or very near tariff change times. The first means of TOD metering which may be called "local TOD metering," is represented by older, more widely used and generally less expensive equipment. It consists mainly of multi-register meters with control devices to shift the record of consumption from register to register as the tariff changes. Such units would normally replace the existing single-register watthour meters, but their function could, in some cases, be duplicated by the addition of a second meter to the existing watthour meter, along with a separate control mechanism for shifting the record of consumption from meter to meter as the tariff changes. Local TOD metering technology also includes magnetic tape recording meters, commonly used for load research, which accumulate consumption data from a watthour meter on one track of a cartridge or cassette tape, while recording time-reference pulses on another track. The consumption data are in the form of pulses, generated by revolutions of the watthour meter disk. Each pulse, representing (for example) one revolution of the disk, thus represents a certain number of watthours. The number of consumption data pulses between two time-reference pulses then measures the energy consumed in that time interval. If the time of day at which the tape is started is recorded, then the time of day is determinable for every time-reference pulse on the tape, and consumption can be sorted out by daily tariff periods. In general, magnetic tape recorders cannot be attached to existing watthour meters, for the latter do not normally contain the pulse-initiating devices required. Watthour meters and recorders are assembled as units and are usually so purchased.

The remote TOD metering approach requires devices for encoding, storing, and transmitting consumption data or demand data from a modified single-register meter, as well as other communications and control equipment.

In virtually every case, implementation of TOD rate

structures requires a change in residential metering. This change, in turn, requires changes in the utility's organization, as well as in the expenditures by the utility.

Metering and Load Research

Both experimentation and implementation of TOD pricing require accurate data on how demand varies over the time of day. What is needed is a continuous or nearly continuous record of the rate at which the customer places demand on the system. Such data are needed not only for the total demand on the utility, but also for different customers. In most cases the only way to disaggregate the demand of a customer from the total load curve is to directly meter the customer in question.

The time of day discrimination capabilities of multi-register meters are usually insufficient for measuring energy consumption over time. At the time of the Projects, the device best suited to this task was the magnetic tape meter. While magnetic tape meters cannot provide continuous demand records with short enough time intervals between time-reference pulses, the average demand per interval is quite close to true demand.

Because, even today, magnetic tape meters are the most available, best developed, and technologically most familiar for load research purposes, they are likely to play a part in any new rate experiments or TOD pricing implementations, whatever the form of metering selected for billing customers.

TOU Rates and Load Management

While the direct goal of TOU pricing is to charge customers as nearly as possible what it actually costs to produce the electricity they consume, in most cases a further effect may be the reduction of the difference between the system's peak and average demand level. Such a reduction would, in most cases result in an increase in the efficiency of the system, and increases in efficiency constitute opportunities to reduce the overall cost of providing electricity.

Considered only in the aspect of the metering and metering-

related system changes it requires, it is difficult to see how inauguration of a TOD rate structure could escape a temporary increase in total operating expense per unit output. Acquiring and installing new or additional metering equipment will add to expenditures. Additional operating expenses per metering point may also be incurred and the same may apply to maintenance expenses. There will be an irreducible minimum cost of research, planning and reorganization, including the cost of new billing procedures which are brought about by the metering change. All in all, TOD metering is a more complex operation than non-TOD metering, comprising more individual tasks, more equipment and more elaborate operational organization than the latter. One of the purposes of the Projects was to gain knowledge of customer responses to the price signals of TOD rate structures. Changes in customer usage patterns may make a system more efficient, and therefore justify the expenditures necessary to change the rate structure.

The link between the TOD rate structure and the eventual shape of the load curve is the aggregate behavior of the system's customers. Some fraction of the customer population will most likely redistribute their consumption of electric power over the tariff periods. This is a complex process involving behavior patterns under the influence of several environmental, psychological, social and economic factors. Some components of this process may, under certain conditions, be rapid, reliable and wide-spread throughout the customer population, while other parts of this reorganization of aggregate consumption habits may take place over a longer period of time. To be sure, the actual rate at which aggregate consumption habits, and hence system load curves, change in response to TOD rate structures is an empirical question, since the very complexity of the process makes its theoretical prediction all but impossible.

On the other hand, virtually all the additional costs associated with the new metering system are operative the moment the TOD rate structures are inaugurated, and there is, at that point in time, a probable increase in the cost of the electricity

generated by the system. Again, one of the purposes of the Projects was to gather empirical evidence to see what happens under the TOD rates, including metering costs.

The changes which take place in the system are more than a change in cost of metering, and one may want to take a longer perspective than simply to add up the costs of change at one point in time and compare them to the cost of not changing. Further, it seem clear that one of the lessons of the Projects is that it takes time to work the "bugs" out of a "new" system. Thus, to pre-judge the results before the system has had time to learn and adjust may be to miss important lessons. Examining the Projects' metering experiences is one way to see how systems may adjust to metering changes. In the next section data on meter equipment selection and cost are examined.

METER SELECTION

The examination of meter selection experiences includes looking at the criteria which appear to have been important in planning these selections. In a way, of course, the criteria are a part of the planning process and, as such, reflect the experiences arising out of the planning of meter selection.

Many agree that a metering scheme should be flexible, economic, legally defensible (accurate) and acceptable to customers.² While not specifically discussed in many of the Project documents, it is evident that a general pattern among Projects was to make flexibility and cost the prime factors in meter selection.³ These will be discussed below.

Although accuracy was important, it was not a legal issue

²Arthur D. Little, Inc., Metering and Communication Systems prepared for the Electric Utility Rate Design Study, January 15, 1977, p. xii.

³Cost is more often mentioned and discussed in the report than flexibility. This may be due to the fact that many of the Projects selected magnetic tape meters which have few flexibility problems.

for the experiments.⁴ Of course meters were tested for accuracy but reports do not include information on legal acceptability. This would presumably be more important under non-experimental conditions. Customer acceptability was not usually considered in planning meter selection. However, in both Vermont and Arizona some specific features of the meters were for use by customers. In Vermont paper recording charts were used so that customers could see how much electricity they were consuming.⁵ The meters in Arizona had lights indicating which register was being used and therefore which rate was in effect.⁶ These features were one way to provide information to consumers but they may also have had an effect on customer acceptability of the meters.

Meter Flexibility Versus Meter Cost

The main area of concern in meter capability is the design of the rate structure. As a rule, the more complex the structure, the more complex the meter.

The flexibility of a meter is especially important in experimentation because of the need to handle different rate structures and fit into the overall system in terms of other demands, such as load management. A primary concern in a number of the Projects was to insure that meter inflexibility or lack of capability did not prevent testing a number of different rate structure designs. For example, in Wisconsin eighteen different two and three-part rates were planned, indicating that metering capability for many rate structures was required.⁷

⁴It is not clear whether this was a consideration in the Projects where participation was mandatory. Since it was possible to bill with a traditional rate or a TOD rate, and since it was an experiment, this condition may have been relaxed.

⁵Vermont Demonstration Project Progress Report, May 7, 1975.

⁶Arizona Demonstration Project Final Report, February, 1978.

⁷Wisconsin Demonstration Project Progress Report, November, 1975.

The rate structure chosen is functionally related to the load characteristics of the system. This in turn affects meter selection. Perhaps the most notable example in the Projects involves a comparison of Ohio and Arizona. The Ohio Project team thought that "weekends" should have a different rate than "weekdays."⁸ This consideration caused a change in meter selection (from dual register to magnetic tape).⁹ In Arizona no such consideration was involved and a meter capable of distinguishing between "weekday" and "weekend" was not used.¹⁰

Another system characteristic is the demand pattern over seasons and holidays. If rates are to take these into account the metering system must have this capability. Seasonal changes were considered in most of the Projects but only Ohio changed the type of metering it was considering due, in part, to seasonal factors.¹¹ The primary reason for the change was given as the need to incorporate a shoulder-rate in the spring and fall seasons, thus requiring an additional register.

A final capability criterion is whether the meter is to gather both billing and load survey data. The decision on what metering equipment to purchase often boiled down to a choice between magnetic tape meters and multiple register meters. A magnetic tape meter is capable of providing data for any TOD rate as well as data for load survey profiles. Unless supplemented, a multi-register meter cannot provide load survey data and cannot provide data for a demand charge. They can, however, provide sufficient data for TOD kwh (energy charge) rates and, properly equipped, allow for weekend exemptions.¹²

⁸Ohio Demonstration Project Progress Report, December, 1975

⁹Ibid.

¹⁰Arizona Demonstration Project Final Report, February, 1978

¹¹Ohio Demonstration Project Progress Report, December, 1975

¹²Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980

All of this indicates that meters with significant flexibility were required in some of the Projects. Consequently, many Projects picked meters which were available, which had been used, and which had the capacity to collect the data they wanted. The "off-the-shelf" metering meeting this requirement was magnetic tape meters and, as stated previously, this type of meter was used in most of the Projects.

The amount of meter selection planning varied rather considerably among the Projects and nowhere is this more apparent than in the selection of magnetic tape meters. Most meter selection planning was done by the participating utility. This usually consisted of discussions with other utilities, relying upon previous experience, and the advice of vendors. Though electric utility companies have not typically use magnetic tape meters for residential billing, they have used them for load research and hence have had some experience with them. An exception to this was the Edmond, Oklahoma Project. In that Project an outside consultant was hired.

It should be pointed out that most of the Projects did not intend to test or experiment with meters or metering technology per se. Of more interest in these Projects were reactions to innovative rate structures or load management equipment. This meant that they wanted data for rate analysis and not necessarily information about what happened in the process of getting that data.¹³

While some of the first generation Projects reported little planning for meter selection, Ohio did a significant amount, and the experience in that Project provides an illustration of some planning considerations.

In Ohio the original intention was to use dual-register-clock-activated meters. However, further inquiry indicated that the type of meter was "too dumb to implement an accurate price

¹³Vermont Demonstration Project Progress Report, May 7, 1975

signal."¹⁴ The main problem was the inability of the meter to distinguish between a weekday and a weekend. Meter selection was further complicated by a change in the planned rate structure from two-period to a three-period.¹⁵ In light of these two changes, two alternatives were then explored: 1) two-register meters, and 2) magnetic tape recording meters. Using a two-register meter was considered only as a means to solve the weekend exemption problem but even then was judged to raise a problem of resetting. Since the hours designated peak, shoulder and off-peak were to vary across seasons, the meter had to be reset.¹⁶ The Project team considered using a radio signal to control (reset) the dual-register meter. The team thought that this would not only solve the problem of resetting but also of accuracy.¹⁷

The second problem was meter reading. Given a seasonal rate structure, all meters must be read before the next seasonal rate goes into effect. A one-way meter control (i.e., radio signal to the meter) cannot overcome this problem. A two-way meter reading system was considered. However, it was judged that manual meter reading was less expensive. Also, questions of the reliability of two-way systems ruled it out even if it were cost justified. The Project team's choices were between using radio controlled dual-register meters and magnetic tape meters. Using the former not only raised the reading problem but the manufacturer required at least 90 days for delivery of a special order

¹⁴Ohio Demonstration Project Progress Report, December, 1975

¹⁵The reason for the rate structure change was given as "The energy cost could not be refined to a 'pure' off-peak cost when the rate would be in effect for all but the very highest peak hours." Ohio Demonstration Project Progress Report, December, 1975

¹⁶This has to be done in a relatively short period of time. This problem is discussed below.

¹⁷The accuracy problem was thought to be two-pronged: 1) does the utility record usage on the right register, and 2) customer tampering. The radio control signal was judged to be more reliable than meter readers, thus a better solution to 1) and more difficult to subvert than a mechanical clock, thus a better solution to 2).

of a dual-register meter with solenoid (for switching registers). This would probably have delayed the Project, in addition to increasing costs by around \$26,000.¹⁸

These considerations tipped the balance in favor of magnetic tape recording meters, and the Project team decided to use magnetic tape meters for both billing and survey meters. The decision was also made to use four-track cartridge meters. This was to allow the meter to record the total household usage and two components (e.g., air conditioner and clothes dryer) with the fourth channel for time pulses.¹⁹ In this connection the metering selection was affected by load research considerations. That is to say that a two track cartridge or a cassette type tape and meter do not have the ability to monitor or record selected components within a household as well as total household usage.

It is interesting to note that the vendor also manufactured a dual register meter with a solenoid switch that was capable of distinguishing between weekdays and weekends.²⁰ The problem was that to get this added capability would have delayed the Project because the vendor did not stock the meter. In order to avoid this delay the Project team ordered magnetic tape meters on the assumption that they would be functional and quickly deliverable. This assumption, no doubt based upon an earlier experience of having magnetic tape meters delivered eleven days after ordering, proved incorrect. A delay in delivery did occur.²¹

The Ohio planning experience highlights the flexibility criterion especially as it relates to system characteristics (e.g., weekend rates). It also points out considerations of cost and reliability in the planning process. In Ohio, as in

¹⁸Ohio Demonstration Project Progress Report, December, 1975

¹⁹Ibid.

²⁰Miller, W.E., "Metering: Topic 7," Electric Utility Rate Design Study, National Association of Regulatory Utility Commissioners, January, 1977

²¹Ohio Demonstration Project Progress Report, December, 1975

other projects, there was a "trade-off" between flexibility and cost. Though Ohio opted for more expensive meters than they had originally planned, cost still ruled out the radio control resetting device for the magnetic tape meters.

The Arizona Project provides another illustration, the other side of the cost/flexibility "trade-off," of planning considerations. That Project team stressed cost rather than flexibility. A decision was made early in the Project that magnetic tape meters were too expensive for use as billing meters.²² At that time a magnetic tape meter cost between \$312 and \$600,²³ while the TOD metering equipment selected in Arizona cost \$151.²⁴

The meters selected in Arizona included some innovative aspects. As will be discussed in more detail later in this chapter, the meter they used was a two meter combination consisting of a two-register and one-register meter wired together so as to produce three registers, one each for peak, mid-peak and total kwh consumption.²⁵ To acquire this metering configuration, Arizona Public Service Company (APS), the participating utility, initiated meetings with General Electric's Meter and Instrument Department to jointly design and manufacture the system. The two worked up and agreed upon the specifications of the meters before they were ordered by APS. Not all of the details of the meter planning process are reported but it is apparent that a number of alternatives were considered.

First there was no mention of whether weekends would be

²²Arizona Demonstration Project Final Report, February, 1978

²³Paul Hart, Arizona Public Service Co. (telephone interview, April, 1980) reported that magnetic tape meters cost \$600 apiece in 1974-75. Others reported costs between \$312 and \$450 at about the same time. The variation in price could be attributable to the volume purchased and the functions ordered.

²⁴See Table 1

²⁵These were used as billing meters but since they were incapable of providing detailed load profile data, 35 magnetic tape meters were purchased. The magnetic tape meters were used to provide the necessary data for rate design.

peak or off-peak. Second, a seasonal rate was used and the meters were to be manually read and reset. Apparently no consideration was given to automatic meter mechanisms or systems. A third feature was that off-peak consumption did not have a separate register. It was arrived at by subtraction. In this case the billing routine was complicated slightly in order to simplify metering.

Another consideration in the Arizona Project was wiring incompatibility. Part of the rejections in the sample were due to the necessity of eliminating some older homes which had only two-wire, single phase service.²⁶ All of the meters were designed exclusively for three-wire single phase service and hence could not be installed in the older homes. It was reported that the problem could have been solved by more expensive meter specifications.²⁷

Battery Carryover

Another consideration, explicitly discussed in meter planning, was battery carryover for the timing mechanism. Whether to use battery carryover was driven by two factors: cost and outage rates. The cost of battery carryover depends upon meter type. A magnetic tape meter battery carryover costs between \$60 and \$80 per unit, but it costs between \$20 and \$30 for a multi-register meter.²⁸ The principal reason for this is that the battery must drive both the recorder motor and the time clock on a magnetic tape meter but only the time-clock on a multi-register meter. Thus, a more powerful battery is required in the former case.²⁹

²⁶Ten percent of this was due to customer refusal while another 49 percent was due to 1) insufficient past history, 2) inaccessible service entrance locations, 3) insufficient space and 4) incompatible wiring.

²⁷Arizona Demonstration Project Final Report, February, 1978

²⁸Telephone interviews, Paul Hart, Arizona Public Service Co. and Lewis Bailey, Blackstone Valley Electric Co., April, 1980.

²⁹Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

The frequency of outage also played a part in whether carry-over was purchased. For example, in Los Angeles outages are rare and the Los Angeles Project team decided not to use battery carry-over.³⁰ In Arizona the Project team intentionally decided not to use battery carryover in the experiments in order to find out if the added cost was justified. They had a fifteen percent reset rate per month and concluded that battery carryover was cost justified.³¹

Other Projects, Puerto Rico and Rhode Island for example, chose to purchase battery carryover.³² A properly functioning carryover device will prevent the loss of data due to an outage and is especially important for magnetic tape meters if more than one outage occurs in a billing cycle. There is a more detailed discussion of battery carryover in Chapter Four.

Institutional Factors

The last planning considerations to be discussed here are labor relations and commission requirements. The degree to which these were planning considerations varies among the Projects. Indeed, some of these were not directly considered on the planning agenda.

Labor relations are not directly mentioned in the reports of the Demonstration Projects. Exceptions to this are Puerto Rico and Ohio where there were strikes by some of the utility employees. These were apparently unrelated to the time-of-use experiments.³³ Whether or not labor relation problems might occur as a result of personal reorganizations or operational changes is largely speculative. However, only one of the Projects, Puerto Rico, rewrote

³⁰Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

³¹Arizona Demonstration Project Final Report, February, 1978

³²See Table 1

³³Puerto Rico Demonstration Project Progress Report, January, 1978 and Ohio Demonstration Project Product User's Guide (no date)

job specifications due to changed responsibilities.

There are two types of labor personnel rearrangement which did surface in the Projects. One was in Edmond, Oklahoma. In that Project, largely due to local political concerns, the City Council wanted to keep some distance between the experiment and city personnel.³⁴ As a result, personnel from a local university, Central State University, were employed to read meters.³⁵ Other types of rearrangement occurred in several of the Projects that used magnetic tape meters. Instead of sending the regular meter readers out, personnel from the meter shop, usually more familiar with the magnetic tape meters, were sent. In those cases where regular readers were sent, they usually received additional training and were instructed to report any malfunction to the meter shop.³⁶ This is more thoroughly discussed in Chapter Four.

Indirectly there are some legal issues relating to metering. Obviously, if a rate structure requiring TOD metering capability is to be implemented the issues relating to the rate bear on metering. Whether a mandatory or voluntary program is to be implemented makes some difference, although under both the specific rate may require utility commission approval. This action can and did have an effect on meter installation. In Vermont they ordered Green Mountain Power to offer an off-peak rate to all utility customers. This order was issued before the community-test phase of the Project was operational. The order had the effect of abolishing customer interest in the non-traditional rate test; since participation in the latter was voluntary, the

³⁴Telephone interview, Upton Henderson, Central State University, April, 1980

³⁵Telephone interviews, Upton Henderson, Central State University and Neil Dikeman, University of Oklahoma, April, 1980

³⁶Telephone interview, Lewis Bailey, Blackstone Valley Electric Co., April, 1980 and Osvaldo Goyco, Puerto Rico Electric Power Authority, remarks at Electric Rate Demonstration Conference Workshop, April, 1980

recruitment of subjects came to a standstill.³⁷

Because the North Carolina Project acquired its metering equipment prior to the authorization of the experimental rates by the public utility commission, their schedule of installation depended, in effect, upon the schedule of relevant rate hearings by the commission. And in fact, the North Carolina Utilities Commission postponed a promised rate hearing which delayed the beginning of meter installation by one month.³⁸ Delays due to commission actions were not anticipated by either Vermont or North Carolina. Nor were such delays anticipated by the other Projects.

METER EQUIPMENT SELECTED

This section provides a summary of the metering equipment the Projects actually used and, to the extent possible, what it cost.

Perhaps the most general pattern of metering selection was the choice of "off the shelf," as opposed to experimental, technology.³⁹ There were exceptions to this, and they will be discussed later in this chapter. Nine Projects used only magnetic tape recording meters for billing. The Vermont and Edmond Projects used two-register, time-switched meters for their two-period TOD billing. Edmond also used magnetic tape meters for load surveys and profiles, and some billing, while Vermont used paper chart recorders for the same purpose. The Arizona Project used an assembly of two watthour meters (one with one register and the other with two) to attain three-period billing capability. They also used magnetic tape meters for load survey purposes. The California Project worked on the development and

³⁷Vermont Demonstration Project Progress Report, December, 1975

³⁸North Carolina Demonstration Project Progress Report, June, 1977

³⁹For the meter equipment selected see Table 1. See also the footnotes at the end of that table for specific reference documents and page numbers.

and field testing of a solid state multi-tariff meter, but did not complete this work in time to use the device in a TOD billing test for residential customers. The New Jersey Demonstration Project undertook the most ambitious metering development of all the Projects: a fully automated two-way meter reading and load control system, using the power distribution network as the communications medium. As is discussed more fully below, implementation of this system was never completed in time for its use in a TOD test.

The selection of meters by the five Projects which did not use magnetic tape meters exclusively is examined later. What follows is an examination of magnetic tape meter selection.

There are actually two types of magnetic tape meter: cassette and cartridge. A cassette machine has only two tracks, while a cartridge machine can have up to four. There does not appear to have been a significant difference in the price of cartridge or cassette recorders.⁴⁰ However, the cassette tape costs between \$8 and \$9, while a cartridge tape costs between \$30 and \$36. Most of the Projects used cartridge type meters, although Los Angeles and Edmond, Oklahoma used only cassette type while Wisconsin used half cassette and half cartridge.⁴¹ There are some operational differences in the two and these are discussed in Chapter Four.

Another variation in the magnetic tape meter is whether it is a three-phase or a single-phase. Three-phase meters are usually used for industrial and large commercial customers while single-phase is used for residential customers. The three-phase price reported in the Arkansas Project, the only one to buy both types, was about \$90 higher than the single phase.⁴²

Some of the Projects bought all of their meters from a single

⁴⁰Wisconsin used half cassette and half cartridge and reportedly paid the same price for the machines.

⁴¹See footnotes at the end of Table 1 for sources.

⁴²Arkansas Demonstration Project Final Report (no date)

vendor. For example, Los Angeles and Edmond bought from Sangamo while Puerto Rico used Westinghouse equipment and Vermont used General Electric. On the other hand, a number of the Projects used multiple vendors. Arkansas and Wisconsin used Duncan, General Electric and Westinghouse magnetic tape meters. The main reason given for the use of multiple vendors was to find out if there were quality or performance differences.⁴³

There were some differences in the prices paid for the magnetic tape meters. The highest per unit price paid by a Project was \$476 while the lowest was \$285. There are a number of possible reasons for these price differences. Chief among them are probably quantity discounts and purchase dates. Los Angeles paid approximately \$285 each for its 1,200 Sangamo magnetic tape meters in 1976, while Edmond paid about \$334 each for its 33 Sangamo magnetic tape meters in 1977.⁴⁴ It is reasonably certain that this was due to a quantity discount, since the purchases were less than a year apart.

Four of the Projects used battery carryover. However, a specific price was available only from Connecticut. The price for the battery carryover was \$64. The unit had an eight hour capacity. The price of the battery carryover was included in the price of the magnetic tape meters in the other three Projects. It is difficult to break it out, since the delivered price of the meter was different in all three Projects.⁴⁵ As previously mentioned, however, a battery carryover for a magnetic tape meter is usually between \$60 and \$80. While it is not known for certain, part of the reason for the price differences may be the length of the carryover time.

Five of the Projects did not use magnetic tape recorder meters. Of these, two selected "experimental" or new technology, and their experiences will be discussed later. The other three--

⁴³See Table 1 for the vendors used in each Project.

⁴⁴See footnotes at the end of Table 1 for sources.

⁴⁵See Table 1 for the price of meters in Rhode Island, Puerto Rico and North Carolina.

TABLE 1
METER TYPES AND COSTS
FOR THE ELECTRIC UTILITY DEMONSTRATION PROJECTS

Project	Meter ^a Type	Battery/ Carryover	Number of Meters Purchased	Vendor ^b	Cost for ^c Meter
Arizona ^d	3 register kwh ^d	No	210	GE	\$151
	MTRM-WR 4	No	35	W	-
Arkansas ^e	MTRM 3 phase	No	50	GE	\$400
	MTRM 1 phase	No	400	W	312
	MTRM 1 phase	No	100	D	312
California ^f	MTRM	No	2000	-	-
	AMR	No	-	AS&E	-
Connecticut ^g	MTRM WR-31	Yes	200	W	\$367 ^h
Edmond, Ok. ^j	2 register	No	245	S	\$ 64
	2 register	No	85		69
	MTRM-SR1 (C)	No	33	S	334
Los Angeles ^k	MTRM(C)	No	1200	S	\$285 ^l
New Jersey ^m	AMR	No	1000	AS&E	-
North Carolina ⁿ	MTRM WR 31SL	Yes	450	W ^o	\$384
Ohio ^d	MTRM	No	300	W, GE, S, D	\$300
Puerto ^q Rico	MTRM WR 31S	Yes	399	W	-
Rhode Island ^r	MTRM PDM-76	Yes	240	GE	\$416 60(BC)
Vermont ^s	2 register	No	40	GE	-
	1 register	No	120	GE	-
	Paper chart recorders	No	120	GE	\$100
Wisconsin ^t	MTRM	No	350	W	
	MTRM(C)	No	350	GE	\$350

(continued)

(Continued)

SOURCE: Compiled from Electric Utility Demonstration Project documents and reports and interviews, 1975-1980. Specific documents are denoted by footnotes below.

- a. Unless denoted by (C), all MTRM's are cartridge type; MTRM= Magnetic Tape Recording Meter, AMR= Automatic Meter Reading
- b. GE=General Electric
W=Westinghouse
D=Duncan
S=Sangamo
AS&E-American Science & Engineering
- c. All prices are rounded to the nearest whole dollar.
- d. Arizona Demonstration Project Final Report, Appendix B, February, 1978.
- e. Arkansas Demonstration Project Final Report, p. III-22, (no date).
- f. Telephone interview, Roger Levy and John Flory, Energy Resources Conservation and Development Commission, Sacramento, April, 1980.
- g. Connecticut Demonstration Project Final Report, May, 1977.
- h. Telephone interview, William H. Bowman, North Eastern Utilities, Connecticut, 1980.
- i. BC=Battery Carryover
- j. Telephone interview, Charles Massey, C. H. Guernsey & Co., Oklahoma City, April, 1980.
- k. Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.
- l. Transcript of telephone conversation, LADWP personnel and Dan Hill, Institute for Social Research, University of Michigan, no date.
- m. New Jersey Demonstration Project Final Report, August, 1978.
- n. Telephone interview, Billy Yarborough, Carolina Power and Light Co., April, 1980.
- o. This was Westinghouse Electric Supply Company, a supplier; not the manufacturer, Westinghouse Corporation.

(Continued)

- p Telephone interview, Henry Duckworth, Dayton Power and Light Co., April, 1980.
- q Puerto Rico Demonstration Project: Procedures of Collection, Translating and Editing of Field Data. (no date)
- r Telephone interview, Lewis Bailey, Blackstone Valley Electric Co., April, 1980.
- s Telephone interview, Porter Cleveland, Green Mountain Power Corporation, April, 1980

Edmond, Oklahoma, Vermont and Arizona--used various types of "off the shelf" watthour meters. The Arizona Project was "in between" regarding meter selection. While they did not select "existing" equipment, neither did they select entirely new equipment. They did not want to use magnetic tape meters but in 1975 there were no three-register meters. To overcome this problem they helped General Electric in the design of a two-meter, three-register configuration. Then in early 1975 they purchased 210 of the meters for their rate test. The meter cost \$102, the meter trough \$43 and the signal light showing which meter was recording demand about \$6 for a total of \$151 each. Additionally, about 50 man-days of in-shop labor were required for wiring, assembly and testing of the meters. This is about four hours per meter.⁴⁶ Since the meter used for billing records was incapable of recording kw usage by time, 35 magnetic tape meters were used to gather load survey data.

The Edmond Project purchased 330 two-register meters from Sangamo for less than \$70 each. The price for 245 of these was \$64 each while the other 85 cost \$69 each. This was not a quantity discount. The vendor made an error on the first bid price but had already delivered part of the meters. It was allowed to raise the price on the second delivery of 85 meters. Edmond also purchased 33 cassette type magnetic tape meters for load survey purposes. They paid \$334 each for the meters.⁴⁷

The Vermont Project used 40 two-register General Electric meters for one of their experimental rates. They also used 120 paper chart recorders in conjunction with single-register meters for other experimental rates. The paper chart recorders were installed indoors and could be seen by customers. In one of the rates, the customer contracted for a set kw demand. If that maximum was exceeded the customer paid a penalty. The paper chart recorders were equipped with a warning buzzer which sounded

⁴⁶Arizona Demonstration Project Final Report, February, 1978

⁴⁷Telephone interview, Charles W. Massey, C. H. Guernsey & Co., April, 1980

when the customer's demand was nearing the contract maximum.⁴⁸ Green Mountain Power Corporation, the participating utility, was able to purchase used paper chart recorders for \$100 each or approximately one-half to one-third the price for new ones.⁴⁹ The price for the one and two-register meters was not available.

The third type of metering selected by the Projects was experimental or "state of the art." These were previously unused (non-field tested) metering devices and were tried in New Jersey and California.

The New Jersey Project undertook to use a sophisticated automatic meter reading (AMR) system for their TOD rates. General Public Utilities had been sponsoring development of this system for over four years prior to New Jersey's original proposal of participation in the DOE demonstration program. At the time of New Jersey's proposal a test version of this system had operated for over a year in New Jersey Central Power and Light service area, over some of the company's longest lines. Application of this system to the demonstration project involved miniaturization of some of the electronic components and a scaling up of the whole system to meet the demands of the experimental design. The aim of the Project was to demonstrate the feasibility of this kind of metering and control technology in widespread peak-load pricing.⁵⁰

Implementation of an AMR system constituted at that time a very significant engineering undertaking. The principal hardware constituents of the system were: 1) a central minicomputer, with appropriate peripherals capable of controlling meter reading for any rate structure, as well as conducting load research and controlling load shedding; 2) six sub-station control units communicating with the central minicomputer by way of telephone

⁴⁸Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980

⁴⁹Paper chart recorders are discussed more thoroughly in Chapter Four.

⁵⁰New Jersey Demonstration Project Final Report, August, 1978

lines, and with the metering points by way of distribution power lines⁵¹ and; 3) one thousand transponders, each attached to a special encoding meter installed in the customer's residence.⁵² The system also included capacitor isolators which allow the power line carrier signals to by-pass the power-factor-correcting capacitor banks normally used in the distribution system. The relatively high frequency signals of the automated system would otherwise be severely attenuated by these capacitors. The complexity of these components, conjointly with the extremely high standards of reliability and accuracy that must be met with any billing-metering application, posed a substantial engineering challenge to the New Jersey Project that was not entirely successfully met.

The experience was duplicated in the California Project. In that Project a similar AMR system was tried. As of this writing the system was not in operation.⁵³ Future attempts to implement AMR systems may suffer from similar problems.

The cost per meter point of an AMR system was not reported in New Jersey but California reported a cost of \$1,500. This included \$500 for installation.⁵⁴ These costs are difficult to evaluate in light of the fact that the system is experimental.

SUMMARY

TOD pricing of electricity and load research cannot be implemented with the standard, one-register watthour meter. Existing metering must be replaced by time-controlled multi-register

⁵¹The function of the sub-station control unit is to relay commands from the central computer to the designated meters and to relay data from the meters back to the central computer.

⁵²The transponder reads the meter in response to commands from the sub-station control unit and transmits metering data back to the sub-station control unit.

⁵³Telephone interview, Roger Levy, Energy Resources Conservation and Development Commission, Sacramento, California, April, 1980.

⁵⁴See Table 1.

meters, magnetic tape meters, or by a remote meter reading system.

Whether or not the goals of TOD pricing are attained depends in part on the specific type of metering selected in a given context. The metering must be flexible enough to exploit the required rate structure, but this flexibility cannot be obtained at such a cost as to nullify the economic effects of the expected improvements in load factor. In general, metering technology capable of use with more complex rate structures costs more than technology limited to the simpler rate structures.

All forms of TOD metering not remotely controlled are vulnerable to time errors due to power outage. Multi-register meters without carryover power sources must be manually reset after each outage, magnetic tape meters without carryover yield erroneous tapes, which must be corrected in data processing whenever power fails. The costs of this resetting or correcting must be weighed against the additional cost of a carryover device for each meter. A determinant of the former costs is the frequency of power outage in the service area.

Nine Projects billed their TOD customers from magnetic tape meters exclusively. Only three Projects used multi-register meters for billing, and of these, only one billed exclusively from multi-register meters. For a number of reasons, discussed later in this report, billing from magnetic tape meters is an unrealistic representation of full-scale TOD implementation. However, the majority of the Projects were concerned with obtaining detailed demand profiles for an informed analysis of responses to TOD pricing. This goal, plus the small size of the experimental samples, made magnetic tape meters the natural preference, despite the fact that the average cost of magnetic tape meters used in the Projects was three to four times that of the multi-register meters used.

CHAPTER: METER ACQUISITION AND INSTALLATION EXPERIENCES
THREE

INTRODUCTION

This chapter contains an examination of the experiences surrounding meter acquisition and installation. These general areas are discussed in terms of two sub-sections. a) planning and b) learning. First is an examination of acquisition and installation planning. In this section acquisition and installation are treated separately. Second is a discussion of the problems and solutions or what is here called "learning."

While the chapter is divided into separate sections it should be pointed out that the total experience reflects a learning continuity. It bears repeating that the overall learning process is important. The experiences are born out of experiments involving fundamental changes in rate design. And, as noted before, these changes require the formation of new habits and the discarding of some working rules and assumptions. Most of the Projects encountered problems in the acquisition and installation of meters and their experiences in this phase of metering provides a rich background for "learning from experience."

PLANNING

Some of the Projects did little in the way of acquisition and installation planning. For example, in the acquisition process a common problem was a delay caused by the vendor being unable to deliver on schedule or delivery of defective meters. Generally, by the time delivery problems were encountered it was too late to solve the problems without delaying the Project. On the other hand, some Projects planned for, and expected, some of the problems they encountered. Yet prior planning was not always sufficient to anticipate and avoid all of the problems. Both the ways in which the Projects responded to these problems, and the occurrence of these problems, form a basis for

future planning and constitute a series of lessons in the implementation process.

At first blush, meter acquisition might be considered a relatively straight-forward task, but eight of the Projects had acquisition problems.¹ Most of these problems were unexpected, which points to a need for enhanced understanding and planning of acquisition routines.

The evidence on acquisition planning is something of a mixed bag. Six of the Projects report some planning activity, though some of it may not be expressly thought of as planning. The other Projects' documentation reveals little acquisition planning. It may not appear to be the case at first but there are patterns to the planning of meter acquisition. For example, two Projects which selected magnetic tape recording meters explicitly planned the acquisition process. Both of these were second generation projects. These two examples were in North Carolina and Edmond, Oklahoma. Both learned from the experience of either the other Projects or other utilities.

In the Edmond Project the consulting firm hired to evaluate existing metering equipment made a recommendation to the Edmond City Council. The recommendation was based partly upon information from both vendors and utilities on various meter capabilities and costs. Part of what was learned was that a meter failure rate of two percent for multi-register meters and ten percent for magnetic tape recording meters could be expected. Acting on this, the consultant recommended that six or seven extra multi-register meters and three additional magnetic tape recording meters be ordered. The City Council approved this recommendation as well as the bid of the vendor selected by the consultant.²

¹See Table 2, p. 44 for a specific listing by project of some of these problems.

²Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980.

In North Carolina a "recorder" committee was formed. This committee consisted of personnel from Carolina Power and Light, Blue Ridge Electric Membership Corporation and the North Carolina Utilities Commission.³ Part of its duties included planning the acquisition of metering equipment. The documentation from this Project specifically states that the reason it planned the acquisition process was because of the experience of the other Projects with vendors. This represents a transfer of learning from the experiences of the other Projects.⁴

One of the things learned in North Carolina was that acquisition delays in magnetic tape recording meters were common; thus they planned for this. Not only did they allow longer lead times for delivery, they put more specificity in the request for proposal. Further, they wrote specific conditions into the contracts. For example, it was suggested that the contracts signed with vendors include: 1) a definite delivery date, 2) a penalty for late delivery, and 3) performance specifications.⁵ The final contract contained these types of conditions. The delivery date was specified, and a monetary penalty was included if this date was not met.

The consensus from the North Carolina Project planning session was that a minimum of three and one-half to four months could elapse between the issuance of a purchase order and the beginning of meter installations. Eight to ten weeks was the estimated delivery time for the recorders, and one to one and one-half months was the estimated time for laboratory testing of the recorders after delivery.⁶

³Telephone interview, Billy Yarborough, Carolina Power and Light Co., April, 1980.

⁴Robert K. Koger, memo, Minutes of Planning Session, North Carolina Rate Experiment Planning Session Participant, August 27, 1976.

⁵Koger memo, op. cit.

⁶Koger memo, op. cit.

A contract for 450 magnetic tape recorders with electronic pulse-initiating meters and 675 tape cartridges was awarded Westinghouse Electric Supply Company on February 4, 1977.⁷ The contract carried eleven specifications regarding performance, size and installation. These specifications, listed below, are examples of a number of planning considerations. The exact specifications called for were:

1. 120/240 voltage capacity
2. 15-minute time pulse intervals
3. 36-day tape duration
4. Two track heads
5. Clock dial with a 12-hour read-out
6. Adaptability--must fit both ring and ringless sockets.
7. Protective enclosure--must be a sturdy weather-proof steel or aluminum box.
8. Installation flexibility--must be suitable for top, bottom or side mounting and adaptable for gang meter base 8 inches wide.
9. Battery carryover is required--a minimum of 5 hours of operation and a battery charge circuit to recharge the battery upon returning it to line power.
10. Must be cartridge type--to utilize Westinghouse or Duncan cartridges only.
11. Must have hard contacts or electronic initiators (pulse initiators)⁸

BREMC received its 200 recording meters in advance of the May 24, 1977 contract deadline. At the same time Carolina Power and Light had received 200 of its 250 allocated meters, also in advance of deadline. Thus, the penalty clause was not activated. However, initiation of meter installation was delayed in the case of both utilities by postponement of North Carolina Utility Com-

⁷It is interesting to note that state regulations required that requests for proposals be let to a long list of contract bidders. The winning (lowest) bid was from Westinghouse Electric Supply Company--not to be confused with the Westinghouse Electric Corporation which manufactured the meters.

⁸Telephone interview, Billy Yarborough, Carolina Power & Light, April, 1980.

mission hearings.⁹

At first it appears that the Ohio project had an acquisition planning function. Upon closer examination it turns out that the acquisition planning in Ohio was not by design but by default. It was selection and not acquisition planning. In fact once it was decided to acquire magnetic tape recording meters acquisition planning apparently ceased. This is probably because three months earlier in the project a vendor had delivered magnetic tape recording meters eleven days after an order was placed.¹⁰ Hence a delay in the delivery of the second order was unexpected. What planning that was done in Ohio indicated that delays of ninety days may have been incurred if they had selected more sophisticated multi-dial meters instead of the dual register meters they had planned on. But no indication of a possible delay in the delivery of magnetic tape recording meters was mentioned.

A reason for planning, however, is documented in the Ohio Project. Although they would have liked to have tested the remote switching meters, the progress of the rate experiment itself might have been delayed. Had the team known of the necessity to have a more complicated rate than they had originally planned and that meter delivery could be delayed, they might have been able to plan their metering capability earlier and thus avoid the potential delay. It would perhaps have allowed them to test other metering equipment if they wished.

Another example of how planning can come about is from one of the DOE Pilot Projects.¹¹ In the Grand River Dam Authority (GRDA) project an unexpected delay in the delivery of magnetic tape recording meters allowed the team to rewrite the specifications for the meters. While prior to the delay there does not

⁹North Carolina Demonstration Project Progress Report, February, 1977.

¹⁰Ohio Demonstration Project Progress Report, September, 1975.

¹¹The Pilot Project program began after the Electric Demonstration Projects and is still ongoing. It involves both rate and conservation implementation projects.

appear to have been acquisition planning, the GRDA experience does indicate a degree of learning from their own acquisition process in time to inject it into future plans. They were able to write more detailed specifications for meter performance. During the delay they had apparently learned of performance problems with the type of meters they had selected.¹²

Other examples of planning are found in Projects which did not have magnetic tape recording meters. Both Arizona and Vermont were first generation Projects which used watthour meters and both did some acquisition planning. The Vermont team discovered that they could purchase used paper chart recorders (which showed customers how much electricity they were consuming) for less than one-half price. This indicates some planning, at least in the shopping end of acquisition. It also indicates that they took into account the prospect of increased customer acceptability and awareness of the metering equipment.

In Arizona, on the other hand, the utility meter shop was intricately involved in acquiring the meters. In fact, Arizona Public Service's arrangement with the vendor in the provision of their two-meter assembly involved the utility meter shop directly in the actual manufacture of this configuration. The meters used in the Arizona Project were unlike those elsewhere. The configuration was worked out because at the time there were no three register meters in manufacture.¹³ The meters were punctually delivered and the only reported problem was that the meter can or trough was more difficult to find than had been anticipated.¹⁴

Installation planning was more directly reported than other phases. Almost all of the Projects did some planning in this regard; others did quite detailed planning. Installation planning involved both technical instructions and instructions on

¹²GRDA Pilot Project Year End Report, October 1, 1977-September 30, 1978.

¹³Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

¹⁴Ibid.

procedures for contacting customers.

While the exact procedure varied somewhat among the Projects, planning began with the selection and interviewing of customers. One distinct planning pattern was to include installers in the interview team. This allowed the installers to inspect the premises and to determine if a TOD meter could be installed. The most usual problems encountered were space limitations and inaccessible service entrance locations. If space limitations were discovered the customer was usually disqualified from the experiment. However, cases where this did not occur were Puerto Rico and Edmond, Oklahoma. Different types and degrees of space limitations were encountered. Perhaps the most pronounced limitations occurred in Ohio. This limitation was partly responsible for a delay in the installation schedule.

The original schedule called for completed installation on January 31, 1976. Installation was actually completed on September 31, 1976 but they met with a fairly high subject rejection rate because of the unusual space requirements of their metering configuration. The entire configuration was about two by three or three by three feet.¹⁵ Their plan to meter individual load components required them to dedicate a separate pulse-initiating watthour meter for each appliance to be distinguished from the total household load. With two distinct components plus total house-hold load to be metered, the typical Ohio Project metering package consisted of three watthour meters and a demand recorder.

Because component metering was used in Ohio the meter configuration had to be installed indoors. This led to three problems: 1) customer acceptance of the meter, 2) sufficient space, and 3) reading access. The first and second problems were solved by eliminating customers from the experiment who did not want the meter installed or where space was insufficient. The bulk of this configuration contributed to the Ohio Project's need to interview 600 customers in order to obtain 100 experimental par-

¹⁵Telephone interview, Mack Wathen, Ohio Public Utilities Commission, April, 1980.

ticipants. Many residences in urban settings would lack sufficient space at the service entrance for this much equipment.¹⁶ The third problem was solved by arranging a time with the customer to read the meter.¹⁷

The problem of locked or inaccessible service entrances was also a concern in Los Angeles and Vermont. In Los Angeles the customer provided access¹⁸ while in Vermont customers were required to provide keys to meter readers as a prerequisite to participation.¹⁹

Interview teams also sought to obtain permission to install the TOD meter during the interview. This was necessary in the voluntary projects, though not the mandatory ones. Related to obtaining permission is the problem of service and reading entrance. This is more of an operation and maintenance concern than an installation one, but an inaccessible entrance also affects installation.

The instructions given to installers also lie in the realm of planning. There is rather considerable variance in how installers were instructed. In some Projects they were told little, if anything, about the experiment. Usually, however, installers were instructed to some extent. A number of the Projects gave the installers instructions on what to say to customers. For example, in the Rhode Island project the installers were briefed as to what was going on. They were told to tell customers that they were part of a load research project being conducted by the government. If the customer had further questions the installers were to refer them to the project manager

¹⁶Ohio Demonstration Project Progress Report, September, 1975.

¹⁷Telephone interview, Mack Wathen, Ohio Public Utilities Commission, April, 1980.

¹⁸Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

¹⁹Telephone interview, Porter Cleveland, Green Mountain Power Company, April, 1980.

and give them the telephone number.²⁰

In the Wisconsin Project stress was put on educating the installers about the nature of the Project so that they felt comfortable in talking to customers about the Project. However, it was also stressed that the installers not say too much or too little about the Project. The emphasis was put on talking with customers about what the Project was about and why it was important as opposed to telling them they were going to be "put on a TOD rate."²¹ Along with instructions to installers tape changers were also briefed. Both groups were informed about the Project so that they would not have a negative attitude about the Project which might be conveyed to the customer. To this end, workshops for meter installers and tape changers (as well as others) were conducted.²²

In the Ohio Project the installers were given instructions to take special care not to change, scar, or scratch the customer's residence. This was because the metering configuration was installed indoors. The installation process could have damaged inside walls, paneling, or other parts of finished interiors.²³

Apart from instructions on customer contacts, installers also received some training in technical matters. In some Projects the utility had previous experience with magnetic tape meters and installers were familiar with the process. In some of these Projects, for example, Los Angeles and Arkansas, installers were also used as tape changers.²⁴

²⁰Telephone interview, Lewis Bailey, Blackstone Valley Electric Company, April, 1980

²¹Telephone interview, Richard James, Wisconsin Public Service Corp., April, 1980

²²Ibid.

²³Telephone interview, John Zulauf, Dayton Power and Light Co., April, 1980

²⁴Telephone interviews, Dennis Whitney, Los Angeles Department of Water and Power, and David Bryant, Arkansas Power and Light Co., April, 1980

In the Edmond Project, the engineering consultant, conducted training sessions for both the installers and meter reader/tape changers. These sessions included specific instruction by the vendor on how to change tapes and install meters. Actual field experience was simulated by first installing a magnetic tape meter on the municipal utility's maintenance shed and then using it to practice tape changing.²⁵ Unfortunately, some of the instructions given by the vendor were incorrect and had to be corrected later by the consultant re-instructing the tape changers.²⁶

In the Arizona Project the meters were received separately and were fitted into the dual socket meter cans for insertion into the single socket at the residence, and appropriate wiring modifications were made on the special meter cans in the utility meter shop. The meter shop also installed indicating lamps (one for mid-peak and one for peak) to alert customers to changes in tariff periods. These procedures resulted in a highly simplified installation routine amounting to little more than the removal of the old meter and the plugging in of the new assembly. The procedure is reported in the Final Report and is exactly reproduced below:

Installation:

In the meter shop:

1. The trough should be suitably prepared to allow the signal leads to be connected to the signal kit at the site making use of the supplied connectors.
2. Meter A should have its signal pigtail connected through the A trough socket and the pot coil pigtail dressed through the A trough socket and out the B trough socket, then the Meter A inserted. Meter B should have its signal pigtail connected through the B trough socket and its pot coil pigtail attached to the A pot coil pigtail, then Meter B inserted.

²⁵Telephone interview, Upton Henderson, Central State University, April, 1980

²⁶Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980

At the site:

1. Remove the house meter.
2. Plug in the trough with Meters A and B already in place.
3. Connect the signal leads to the signal kit.

(Note: Variations from the above suggested installation procedure will have to be made depending on the signal connection methods.²⁷)

LEARNING

This section is divided into two parts: problems and solutions. It is designed to highlight and examine many of the experiences encountered in acquisition and installation. In some cases the solutions are part of the discussion. This is the case where the solution was part and parcel of the problem. However, a second section is on solutions per se. Much of this section illustrates learning from the problems encountered by the Projects.

Errors and Delays

Many of the problems associated with acquisition and installation have to do with errors either by the Project team, the vendor or some other associated party. These problems form a basis for learning from the experience. A number of the errors in either acquisition and installation did not surface until the experiment was in operation. Some of the difficulties can be characterized as errors basically due to the novelty of this kind of metering change. For example, the vendor of the magnetic tape recorders used in the Connecticut Project supplied some 30-day tapes in place of 90-day tapes ordered. The participating utility had no routine check in place for this kind of vendor error, as its incidence was then unestimated. The result was that the error was not discovered until the first tape change of the Project in

²⁷ Arizona Demonstration Project Final Report, Appendix B, February, 1978

October of 1975, one month of data being lost as a consequence.²⁸ Difficulties in the editing of the data were incurred by this discrepancy between the actual tape length and the assumed length.²⁹

When the North Carolina Project personnel began reviewing bids by the vendors of the magnetic tape meters, they discovered that different vendors had understood the request for proposal in different ways, and consequently had to issue a second request for proposal. This caused an overall delay in the Project of four months.³⁰

The Edmond, Oklahoma metering consultant recommended purchasing seven or eight multi-register meters and two magnetic tape meters extra in case of meter defects. These numbers were based on a two and ten percent failure rate, respectively. However, the meter installers installed all of the meters, thus exhausting the reserve stock.³¹ This was remedied by a request for additional DOE funds for 25 meters to make up a 7.5 percent reserve stock. But by the time of this additional request, mechanical difficulties with several of the multi-register meters had already made it impossible to complete installation on schedule.³²

Either unforeseen special requirements in their test populations or reconsiderations of their metering requirements caused some of the Projects to deal fairly extensively with vendors subsequent to the initial orders of equipment. The Puerto Rico

²⁸Connecticut Demonstration Project Progress Report, October, 1975

²⁹Connecticut Demonstration Project Product User's Guide (no date)

³⁰Letter, Miedema to Christopherson, January 26, 1977 (DOE files)

³¹Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980

³²Letter, Buntz to Paquin, August 12, 1977 (DOE files)

Project had to have thirty of its meters modified by the vendor to fit special bases on condominium buildings.³³ The Grand River Dam Authority renegotiated their contracts with the equipment vendors during a delay in fulfilling the initial orders to obtain more efficient and reliable meters and a more powerful tape translator. This change in contract cost the utility an additional \$70,000.³⁴ The New Jersey Project affords several examples of the need to modify equipment specifications after the initial contract. Indeed, virtually every major component of the automatic meter reading system required some redesign or respecification during the course of the Project.

Some of the operational problems which developed early in the demonstration projects were attributable to defective or inappropriate goods supplied by vendors but not detected in time. Others are attributable to installation errors. Two varieties of meter malfunction were detected early in the operational phase of the Puerto Rico Project. In some cases the capacity of the battery carryover seemed to have been exceeded, resulting in loss of time-signals during power outages. This was partly due to the frequency and length of outages in the PRWRA system,³⁵ but it was determined that some of the meters were installed with partly or completely discharged batteries, making them incapable of carrying over any significant outage.³⁶ Such errors as this are probably characteristic of the early, "pre-habitual" stages of any new metering operation. The other malfunction was erratic operation of the tape-drive motor in the recorders. Some ten percent of all new meters had eventually to be replaced for this

³³Puerto Rico Demonstration Project Progress Report, July, 1978

³⁴GRDA Pilot Project Year End Report, September, 1978; memo, Jackson to Kaseman, May, 1978

³⁵Puerto Rico Demonstration Project Progress Report, March, 1979

³⁶Memo, Bennis to Johnson, September 14, 1978 (DOE files)

reason.³⁷ This kind of defect probably can be detected only by extended running of the recorder motors during bench test, a procedure that might incur unacceptable delays in meter installation.

Some of the magnetic tape used in the Los Angeles Project turned out to be perforated with multiple holes, requiring the establishment of a policy of inspecting every new tape prior to its installation. In another batch of tapes there was an excessively thick magnetic coating, which prevented the cassette from winding fully. Fifteen days of consumption data were lost because of this defect.³⁸ A solution to the problem offered by the manufacturer was to increase the tension in the spring drive so that the tape would pull through. This solution resulted in breaking the tapes, and hence losing the metered data.

There is, of course, an irreducible incidence of meter failures due to defective goods delivered in spite of the most careful inspection and testing. For example, the Edmond Project had from six to eight meters that recorded all consumption on one register.³⁹ Also, in the Edmond Project it is interesting that a defect rate of two percent was expected on multi-register meters but it was ten percent. Conversely, a ten percent defect rate was expected on the magnetic tape meters but five percent were defective.

Apart from errors, the process of actual acquisition and installation can experience delays. A number of factors can delay the process. Some are due to acquisition problems, others are due to installation. The introduction of new metering equipment, even in a relatively small fraction of the service population, is a sufficiently complicated and unusual undertaking and makes

³⁷ Puerto Rico Demonstration Project Progress Report, March, 1979

³⁸ Documentation and Review of the Los Angeles Demonstration Project's Data Collection and Editing Procedures (no date)

³⁹ Edmond Demonstration Project Progress Report, November, 1977

⁴⁰ Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980

swift accomplishment of the task unlikely. Indeed, the typical experience of the Projects involved delays and difficulties in both acquisition and installation of the metering equipment. The Arizona, Arkansas, Los Angeles and Connecticut Projects were notable exceptions in their attaining, or nearly attaining, originally planned schedules of acquisition and installation. The Arizona Project had completed all installations within four months of obtaining permission from the experimental customers.⁴¹ The Arkansas Project planned for delivery of its 300 magnetic tape meters by the end of October, 1975. The first shipment arrived precisely on schedule, and all installation was completed by early December of that year.⁴² Similarly, the Connecticut Project accomplished its installation within five months of the beginning of the period of performance on the DOE cooperative agreement. Two hundred test meters were installed in control residences in a single month.⁴³

Delays due to late delivery by vendors occurred in eight of the Projects and at least one pilot project, GRDA. The length of the delays varied. Wisconsin, on one extreme, had a one month delay while delays in this and other aspects of the New Jersey Project, on the other extreme, eventually caused DOE to terminate the Project.

The Wisconsin Project planned to begin installation of 700 magnetic tape meters on December 8, 1975, and to complete installation by March 15, 1976.⁴⁴ Their detailed schedule was to install 100 meters in December, 1975; 300 in January, 1976; and the remaining 300 throughout February and early March, 1976.⁴⁵ By

⁴¹Arizona Demonstration Project Product User's Guide (no date)

⁴²Arkansas Demonstration Project Progress Report, December, 1975

⁴³Connecticut Demonstration Project Progress Report, September, 1975

⁴⁴Wisconsin Demonstration Project Progress Report, October, 1975

⁴⁵Wisconsin Demonstration Project Progress Report, November, 1975

TABLE 2

PRINCIPAL TOD METERS, AND THE LENGTH AND REASON FOR ACQUISITION AND INSTALLATION DELAYS

Project	Principal TOD Meter Type	Length of Delay	Principal reasons for delay/remarks
Arizona	1 + 2 reg. watt-hr. combination	None	There was some difficulty in obtaining the dual socket can for meter configuration but this did not cause a delay.
Arkansas	MTRM ^a	None	
Connecticut	MTRM	None	
Edmond, Okla.	Multi-reg., some MTRM	5 mo.	1. Lack of spare meters to replace defectives. 2. Diversion of personnel to repair storm damage. 3. Incompatibility of some meter bases.
GRDA, Okla	MTRM	None	
Los Angeles	MTRM	None	
New Jersey	AMR	4 yrs. (installation never started)	Need to redesign, modify, repair, etc. nearly every component of advanced automatic meter reading system several times.

(continued)

TABLE 2 (continued)

Project	Principal TOD Meter Type	Length of Delay	Principal reasons for delay/remarks
North Carolina	MTRM	4 mo.	Need to reissue request for proposal not uniformly interpreted by vendors of metering equipment. Commission Rate Hearing
Ohio	MTRM 1 dial kwh	8 mo.	1. Acquisition of "more sophisticated" metering equipment took longer than planned. 2. Need to interview some 600 customers to obtain sample of 100: space requirements at service entrance too great for many residences.
Puerto Rico	MTRM	18 mo.	1. Vendor could not meet delivery schedule. 2. Major strike halted installation. 3. Installation at replacement residences a lengthy process. 4. Installation retarded by installers' having to collect tapes from meters already in place: the more meters installed, the slower the remaining meters are installed.
Rhode Island	MTRM	7 mo.	1. Vendor could not meet delivery schedule. 2. Some defective meters returned for repair/replacement.

(continued)

TABLE 2 (continued)

Project	Principal TOD Meter Type	Length of Delay	Principal reasons for delay/remarks
Vermont	2-reg. (TOD) G-9 Paper Chart Re- corder	2 mo. (1st step of test) 7 mo. (2nd step of test)	Acquisition delays. During delay new off-peak rate became available state-wide, causing loss of customer interest in 2nd step of rate test; volunteers became nearly impossible to recruit.
Washington		No TOU rate test as such, but acquisition of special meter with TOD capability delayed 20 months by design/development problems.	
Wisconsin	MTRM	1 mo. (approx.)	Delays in delivery of meters from vendor.

^aMTRM = Magnetic Tape Recording Meter

Source: Compiled from Electric Utility Demonstration Project Reports and Documents and Interviews, 1975-80.

January 31, 1976, installation was 321 meters behind schedule largely because of delays in meter delivery by the vendor. The utility was able to install 604 meters in the two months of February and March, 1976 indicating that little, if any, of the earlier slippage was due to problems with installation itself. Installation was completed in early April, approximately one month behind the original schedule.⁴⁶

The Puerto Rico Project affords an interesting example of the chain reaction that can be set off by untimely delivery of meters. The Puerto Rico Water Resources Authority (PRWRA) planned to have all of its magnetic tape meters installed by early summer of 1977. While there were substantial delays in equipment delivery, the most serious ones were incurred during the installation phase. By April of 1977 350 magnetic tape meters had been ordered from Westinghouse with plans to have them all installed by the early summer of that year.⁴⁷ By late May/early June, 1977, a delay had occurred in the delivery schedule; now all meters were expected to be in the hands of the utility by late July of 1977, thus installation had slipped behind schedule.⁴⁸ Despite this delay, baseline data collection was still expected to begin on schedule (August 1, 1977). However, the meters were not delivered until September of 1977. By the beginning of October, 1977 they had all been checked and repaired,⁴⁹ but by January, 1978 installation was still not complete. Some twenty of the meters to be used in condominium buildings were still in the Westinghouse factory for modifica-

⁴⁶Wisconsin Progress Reports for December, 1975, through January, 1976, and March, 1976, and Wisconsin, Quarterly Progress Report, April - June, 1976.

⁴⁷Document: Questions and Answers Relating to the Puerto Rico Draft Masterplan (no date).

⁴⁸Puerto Rico Project Continuation Request for fiscal year 1977-78.

⁴⁹Puerto Rico Second-year Workplan/First Quarterly Report, 1977-78.

tion to enable them to fit the base used in such buildings. In the meantime a major strike had begun at PRWRA on December 27, 1977 and was destined to last until April 23, 1978, during which time meter installation was at a standstill.⁵⁰ Installation of meters did not begin until June 14, 1978. Considerable spare metering equipment was ordered on May 11, 1978, delivery being promised by the vendor within six to eight weeks, but as late as October 31, 1978 several components of this order had not yet been delivered.⁵¹ In the first month of installation, from June 14 to July 12, 235 out of the required 400 demand recording meters were installed,⁵² but in the period from July 15 to October 31, 1978 only 129 new meters were installed. All meters were finally installed in early January, 1979, fifteen months after their initial receipt, checking and repair by the utility.⁵³

The length of the delays can vary but the extreme example was in the New Jersey Project. This was primarily an acquisition delay and constitutes a special case, one that clearly illustrates the difference between adoption of more or less standard TOD metering equipment and the development of "state-of-the-art" equipment. Actually, the New Jersey Project suffered almost all its delays in acquisition rather than in installation, since designing, prototyping, arranging for manufacture, etc., occupied nearly all of the project's duration.

The equipment selected for the experiment posed a unique challenge that made it difficult to meet within the time-frame proposed. As matters turned out, the designing, production, installation, testing, modification and repair of the system occupied almost four years without attaining operational status.

Long lead-times in the delivery of some components were

⁵⁰Puerto Rico Demonstration Project Progress Report, January, 1978.

⁵¹Puerto Rico Demonstration Project Progress Report, July, 1978.

⁵²Puerto Rico Demonstration Project Progress Report, October, 1978.

⁵³Puerto Rico Demonstration Project Progress Report, March, 1979.

incurred right from the beginning by the decision to employ large-scale integrated circuits in the transponders and transponder control equipment. Design work on the transponder control electronics began in September, 1975.⁵⁴ The contractor to manufacture the 1000 transponders was not chosen until February, 1977.⁵⁵ The large scale integrated circuits for all 1000 transponders were ordered by June, 1977.⁵⁶ but by September, 1977 there was still no delivery of the transponders, due to further design difficulties, and new instructions had to be issued to the manufacturer.⁵⁷ Two months later the transponders were being redesigned.⁵⁸ The first shipment of transponders was not received until late April, 1978.⁵⁹ but as late as May, 1979 another defect in the transponders was discovered, and all 1000 had to be returned to the manufacturer.⁶⁰

Construction of a prototype sub-station control unit was under way by March, 1976.⁶¹ More than two years later three of the six sub-station control units had to be returned to the vendor due to malfunctions in the power amplifier sections.⁶² Similarly, it was well over two years from the first issuance of request for quotes to potential manufacturers of the capacitor isolator to passage of initial tests by the first prototype isolators delivered.⁶³ During this time a capacitor isolator vendor had to be changed.⁶⁴ The specifications of the central

⁵⁴New Jersey Demonstration Project Progress Report, September, 1975.

⁵⁵New Jersey Demonstration Project Progress Report, February, 1977.

⁵⁶Letter, Jones to Windes, July 1, 1977 (DOE files).

⁵⁷New Jersey Demonstration Project Progress Report, September, 1977.

⁵⁸New Jersey Demonstration Project Progress Report, November, 1977.

⁵⁹New Jersey Demonstration Project Progress Report, April, 1978.

⁶⁰Letter, Grygiel to Johnson, May 7, 1979 (DOE files).

⁶¹New Jersey Demonstration Project Progress Report, March, 1976.

⁶²New Jersey Demonstration Project Progress Report, June, 1978.

⁶³New Jersey Demonstration Project Progress Report, February, 1976 and June, 1978.

⁶⁴New Jersey Demonstration Project Progress Report, March, 1978.

mini-computer were completed in October, 1975,⁶⁵ but not until February of 1978 was the computer actually set up for field testing with portable transponders and "pilot" programs instead of the final software package to be used in actual implementation of TOD rates.⁶⁶ In June of 1978 it was determined that this final software package would require considerable debugging to become fully operational.⁶⁷

Another source of installation delay was structural. Many houses in the Puerto Rico Project area had their meters enclosed behind iron grillwork, which often restricted the space available at the service entrance for the larger TOD metering packages. As a partial solution to this problem, PRWRA prepared cable extensions, to be plugged into the meter base thus allowing the meter to be mounted outside the old enclosure.⁶⁸ Even so, some sixty failures of installation occurred for such reasons as corroded or otherwise unsuitable meter bases and lack of clearance for the meter. A situation similar to this occurred in Edmond, Oklahoma. Part of the reason for installation delays there was that some twenty of the customers in the sample lived in old homes that were found to have meter bases not adaptable to the multidial TOD meters, or to the magnetic tape meters.⁶⁹

Puerto Rico also experienced an installation delay which is traceable to a planning flaw. Installation of meters began on June 14, 1978. In the first month 235 out of the required 400 meters were installed. But in the next three and one-half months only 129 new meters were installed. Part of this marked slowdown resulted from two causes: 1) the fact that customer interviews were not already completed before the second month of installation began (the 235 customers who received their

⁶⁵New Jersey Demonstration Project Progress Report, October, 1975.

⁶⁶New Jersey Demonstration Project Final Report, August, 1978.

⁶⁷New Jersey Demonstration Project Progress Report, June, 1978.

⁶⁸Puerto Rico Demonstration Project Progress Report, July, 1978.

⁶⁹Edmond Demonstration Project Progress Report, August, 1977.

meters between June 14 and July 12 had been interviewed during the strike); and 2) the fact that the field personnel who installed meters were also responsible for tape collections from meters already installed. This meant that the more meters already installed, the slower the rate of new installation.⁷⁰ All the meters were finally installed in early January of 1979, fifteen months after their initial receipt, checking and repair by the utility.⁷¹

Yet another installation problem was incompatible wiring. This problem was reported in both Arizona and Puerto Rico. The main source of difficulty was the existence of some homes with two-wire, single phase instead of three-wire single phase wiring servicing the residence. All of the meters were designed for three-wire service. When this was encountered in Arizona the customer was removed from the sample. The solution they suggested was more expensive meters and insuring that some portion of the meters were two-wire.

Vermont affords an example of the interaction between metering installation and load control equipment. It is also spiced with the additional wrinkle of the PUC passing a new rate reform requirement while the experiment was still in progress.

The Vermont Project's test of non-traditional rate structures comprised two phases: 1) a test of six non-traditional rate structures on 120 volunteer customers, followed by, 2) the comparison of an experimental and a control community, under one or more of the more promising non-traditional rate structures as determined by the results of the volunteer test.⁷² Delays in equipment delivery did interfere in installation of meters for the subsequent community-test phase. The scheduled completion date was revised from August 15 to October 1, 1975, but as late as December, 1975 not all community-test metering

⁷⁰ Puerto Rico Demonstration Project Progress Report, July, 1978.

⁷¹ Puerto Rico Demonstration Project Progress Report, March, 1979.

⁷² Vermont Demonstration Project Progress Report, May, 1975.

was installed.

The original schedule of the Vermont Demonstration Project required TOD metering on the 120 volunteer customers from the six non-traditional rates to be fully operational by June 15, 1975. By the end of the first quarter of 1975 twenty metering packages (of different composition for different test rates) were in place and operational in residences on the off-peak experimental rate. At that time the remaining 100 metering packages were on hand and ready to be installed.⁷³ By August 15, 1975 all 120 metering installations were complete and fully operational in the non-traditional rate study. All start-up problems had been resolved.⁷⁴ The extension of the non-traditional rate study to a community test was to be operational by November 1, 1975. This test could apply the more promising of the non-traditional rates to one of two master-metered communities, the other to serve as a control. Master metering of these communities was to begin June 1, 1975. A ripple control system (ordered during the first quarter of 1975) was to be installed along with other load control equipment during September and October, 1975.⁷⁵

During the second quarter of 1975 the community test had fallen behind schedule due to delays in equipment delivery, although it was still expected that full installation would be attained by October 31, 1975 as originally planned. The original delivery date of August 15, 1975 for the metering equipment was revised to October 1, 1975.⁷⁶ By the end of September, 1975, both the master and individual meters for the community test were still scheduled for installation.⁷⁷ Now the full operational date for the community tests was December 31, 1975. At this time

⁷³Vermont Demonstration Project Progress Report, May, 1975.

⁷⁴Vermont Demonstration Project Progress Report, August, 1975.

⁷⁵Vermont Demonstration Project Progress Report, May, 1975.

⁷⁶Vermont Demonstration Project Progress Report, August, 1975.

⁷⁷Vermont Demonstration Project Progress Report, September, 1975.

contracts had not been signed nor had the individual equipment been installed, although master meters for the communities were partially installed.⁷⁸ As the project team remarks in this report that the metering equipment to be used in the community tests is "very simple to install and should be achieved in a matter of days," it seems clear that there had been substantial delays in the delivery of this equipment, rather than difficulties in the coordination scheduling and execution of actual installation.⁷⁹ By the end of December, 1975, the metering equipment for the community tests was either on hand or installed. However, the community tests of non-traditional rate structures apart from the ripple control of interruptible service was at this time "just about at a stand-still." Before the test could be fully implemented, Green Mountain Power, in response to directives of the Public Service Board, announced their offer of an off-peak to all residential customers. This announcement had the effect of destroying customer interest in the experimental rate program. As the community test was a voluntary participation experiment, it had become all but impossible to recruit customers for the other non-traditional rates to be tested.⁸⁰ During the fifth quarter of the Project the ripple system test was unexpectedly delayed by operating problems and a resulting manpower shortage which halted installation of the primary metering equipment was not yet complete. Installation was to be completed by June 1, 1976.⁸¹ The operating problems which resulted in delays in meter installation appeared in the metering and electrical maintenance departments of Green Mountain Power Corporation.⁸²

⁷⁸ Ibid.

⁷⁹ Ibid.

⁸⁰ Vermont Demonstration Project Progress Report, December, 1975.

⁸¹ Vermont Demonstration Project Progress Report, March, 1976.

⁸² Ibid.

SOLUTIONS

Actually a number of solutions have already been discussed. However, there are a few which have not and some of those that have can be stressed again. The experience in North Carolina of writing detailed specifications, as well as anticipating possible delays, is an example of what might be done to plan the acquisition of metering equipment. In order to do this, as the North Carolina experience shows, there must be a clear idea of what equipment is required and how it is to operate. While the participating utilities had some previous experience with magnetic tape meters, it is clear from the documentation that the experience of the other Projects provided input into that project, at least in the area of planning for acquisition. They set up a "recorder" committee, one of whose functions was to select and acquire metering equipment.

Other specific examples of solutions to installation problems include such things as overcoming structural problems and space problems. As mentioned previously, Puerto Rico was confronted with meter housing made of heavy iron grill which were too small for the magnetic tape meters. Part of this was overcome by cable extensions which allowed the meter to be mounted outside the grillwork. It may be possible to use a cable extension in cases where the space for the present meter is too small for TOD meters. This, however, raises the issue of customer acceptance. There were cases where the customer did not want even very short cable extension from the meter to the recorder because of the appearance.

Installation problems can sometimes be considered in acquisition planning. The specifications for installation could solve some of the problems of meter location and lack of space for the installation. Also, a specification on meter width, such as the eight inch specification in North Carolina, may solve space problems.

Because there are many possibilities of difficulty, error and delay in the entire acquisition and installation process, a

collaborative relationship between utility and vendor, rather than formal purchase and sale, seemed to overcome some acquisition problems. For example, the entire operation of the New Jersey Project, involving as it did the tailoring of so much advanced equipment to the specific needs of a particular utility, depended throughout on close cooperation between the utility and several vendors of that equipment. One illustration from the New Jersey Project of the importance of this relationship is the lengthy and difficult history of the capacitor isolators, which were essential to the operation of the automatic meter reading system in the presence of power-factor-correcting capacitor banks. The vendor's response to the first request for a quote on the capacitor isolators brought about respecification of those items. Continued difficulties in their manufacture led to two redesigns and culminated in the substitution of a new vendor for one already under contract late in the project.⁸³

Another example of this cooperation was in Puerto Rico. As mentioned previously, the demand recorders used had a significant incidence of malfunction in the tape drive motors. The impact of this problem was considerably mitigated by the cooperative attitude of the vendor, which continued to replace the defective meters even after expiration of the guarantee.⁸⁴

Perhaps the most often discussed or mentioned solution to acquisition problems related to defective goods was in-house quality control. It was suggested by a number of parties that an "in-house" quality control is important. It was said that this would go a long way toward solving many of the problems of defective goods. This is no doubt true and points again to the nature of change involved in TOD rates. It is important, however, for the quality control personnel both of the utility

⁸³New Jersey Demonstration Project Progress Report, March, 1978.

⁸⁴DOE file notes of government technical representative Paul Johnson, July 11, 1979.

and the vendor to have an idea of what to look for in the way of defects or possible operation problems. This is where the experience from operation and maintenance feeds back into the learning process. Once the system has been operational, what is learned there can feed in to the acquisition and shop testing procedures.

SUMMARY

The planning of meter acquisition primarily concerned securing adequate reserve stocks, avoidance of delivery delays, and assurance of performance standards in equipment delivered. One high point of acquisition planning was the specification of delivery dates, late-delivery penalties, and performance standards in contracts let by the North Carolina Project. Another was the involvement of Arizona Project personnel in the design and construction of a special multi-register metering configuration.

Installation planning involved preparing to deal with space limitations at the service entrance, inaccessibility of service entrances, and incompatible wiring. Particular account should be taken of the problems that can arise if a substantial fraction of installations must be indoors: customers may be less likely to accept the new metering; space limitations are likely to be worse; and reader access will likely be more difficult. How installers communicate with customers may have a significant effect on acceptance and participation, and should be subject to some control during the planning phase.

Defective equipment and equipment delivered late hampered a number of Projects. Delays in final installation of meters were due in part to such vendor errors but also to planning, training, and quality control insufficiencies on the part of the utility.

Many problems of acquisition and installation can be lessened by close cooperation between the utility and the vendor, along with a well-planned program of quality-control of materials received by the utility from all vendors.

:
CHAPTER :
FOUR : THE OPERATION AND MAINTENANCE OF TOD METERS
:

INTRODUCTION

All forms of TOD metering call for more effort in their operation and maintenance than does single-register metering. But the various TOD technologies have different operational requirements, and they differ from one another in both the type and frequency of maintenance problems. The actual experience in operation and maintenance of a TOD system will have a lot to do with the kind of metering selected. The planning of operation and maintenance required in implementing TOD pricing will be heavily determined by what is known about the operational idiosyncracies and vulnerabilities to malfunction of the chosen technology.

In this Chapter, we contrast the types of TOD metering used in the Projects according to four main phases of operation and maintenance. The phases are: 1) collection of data from the meter; 2) handling of data from meter to bill-preparation; 3) prevention/correction of malfunctions, and; 4) dealing with power outage effects. This analysis differentiates between the two forms of TOD metering actually used by the Projects for rate demonstration purposes: 1) multidual and 2) magnetic tape metering.

A third major type of TOD metering is an automatic meter reading system. It uses two-way communication between the meters and a central collection/control station and can be differentiated from the others according to these components of operation and maintenance. This technology is represented among the Projects, in the developmental work of the New Jersey and California Projects. But neither Project actually carried this advanced technology past the developmental stage and into continuous operation on a significant scale. Real operational and maintenance data on automatic meter reading systems do not occur in the Project experiences. The best that can be done respecting

the operation and maintenance of such advanced systems is to note that in certain phases of some Projects there were non-metering applications of communications technology as complex as that involved in automatic meter reading.¹ Where the experiences with this technology seem pertinent to metering issues, they will be discussed.²

Cutting across both the types of metering and the phases of operation and maintenance is the distinction between what was foreseen and planned for and what was learned in the course of actually using the equipment. As in other aspects of TOD pricing, this distinction is essential to a correct assessment of overall feasibility. Only a close monitoring of the learning that goes on in new implementations can distinguish their intrinsic difficulty from problems that will disappear as the new practices become old habits. To be sure, TOD metering is fundamentally more complex than non-TOD metering and complication brings greater opportunity for problems. But experience and memory can, with proper motivation, prevent the recurrence of problems. It would be wrong to dismiss TOD pricing on the grounds that we do not now know how to meter electrical consumption by time-of-day as easily, cheaply and accurately as we

¹These applications involved one-way, not two-way communications links and, hence, could not be applied directly to automatic meter reading. The radio-control used in the Ohio Project is intrinsically limited to meter control rather than meter reading because of the unfeasibility of placing adequate transmitters at the metering points. The ripple system used by the Vermont Project could in principle be transformed into a two-way medium. Two-way ripple systems are currently under development.

²It is possible to make a reasonable prediction of the operational and maintenance problems of any automatic meter reading system installed on a large scale in the near future: they will be grave. These systems depend on the coordinated functioning of numerous separate components, each of which is a complex of fallible parts. The technology embodied in some of these parts is quite new. A vast increase in the number of opportunities for malfunction and error, plus the facilitation of oversight and error that usually accompanies technological novelty, makes untroubled application the least likely of all outcomes. Other benefits of such systems, besides metering, may make the problems and resulting expenses, bearable.

meter it by the whole billing period. It would be as wrong to do that as it would have been to dismiss pricing by consumption on the grounds that--as once must have been the case--watthour metering was difficult, inaccurate and expensive. Thus, whenever possible in what follows, stress is put on the value of the operation and maintenance experiences of the Projects as learning for the benefit of future TOD implementations.

METER READING - DATA COLLECTION

The duties of meter readers differ markedly between multi-dial and magnetic tape TOD metering. With the former technology the procedures of data collection are only a little more complicated than single-dial, non-TOD meter reading. The meter reader must still record an appropriate identification of the meter, the date and the time. All that is added is the reading of two or more registers instead of one. The magnetic tape collector, on the other hand, must perform every operation of standard meter reading, plus tape exchange and the recording of the tape start and stop times to the minute. While the working data are on the tape, the magnetic tape meter also has a regular watthour register, the total kwh reading from which provides an indispensable check on the validity of the magnetic data. Likewise, the collector's record of the exact tape-change time is essential to tape validation for reasons that will be discussed later under "Outage Problems."

It is possible for these additional duties of the magnetic tape meter reader to require official rewriting of this job description which could, in turn, precipitate a labor difficulty like the one confronted by the Puerto Rico Project. The operating union of the Puerto Rico Water Resources Authority refused to allow member meter readers to collect tapes unless the Authority rewrote the job description for all readers. Rather than do this, the Authority chose to hire three new personnel and to add data collection duty to those of three other non-meter readers.³

³Summary, Puerto Rico Demonstration Project Quarterly Review

Because magnetic tape collection affords more occasions for error than multidial meter reading, more careful and extensive training of personnel is necessary in the former case than in the latter. Here is an instance of how greater constraints are placed on operation and maintenance planning by magnetic tape metering, for the training of personnel is an integral part of such planning. The utility should not rely on written instructions only, however detailed; hands-on experience with the operations is necessary. In some of the Projects the metering personnel responsible for meter installation and tape collection were already very experienced with this type of equipment before the Projects began. Dayton Power and Light (in the Ohio Project) had been using magnetic tape meters since 1967; the people responsible for installation and collection were the same who had operated the magnetic metering all along.⁴ The corresponding personnel in the Los Angeles Project were meter testers, already familiar with magnetic tape operations from previous load survey work.⁵ Other Projects found it necessary to provide specific, formal instruction in the operation of magnetic meters. The Arkansas Project held both the pre-Project training sessions and review sessions during the test itself.⁶ The Edmond Project gave formal instruction and set up demonstration meters for the training of meter readers in the operation of both tape and two-dial meters.⁷ The importance of adequate training in magnetic tape data collection is underscored by an experience of the Edmond Project. They had the metering vendor, Sangamo Weston Corporation, train their personnel in the operation of the 33 recording

Meeting, January 5, 1977.

⁴Telephone interview, John Zulauf, Dayton Power and Light Co., April, 1980.

⁵Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

⁶Telephone interview, David Bryant, Arkansas Power and Light Co., April, 1980.

⁷Telephone interview, Upton Henderson, Central State University, April, 1980.

meters used in conjunction with the two-dial meters. Because the initial instruction was incorrect, one month's data were lost from 31 of the meters, and the collectors had to be re-trained.⁸

There is a particular error of tape exchange that should receive emphasis in data collection training where cassette tapes are used. Cassettes have non-magnetic leaders and trailers on which nothing can be recorded. If the cassette is set to run without winding its tape past the clear leader, or if it is pulled after it has wound down to the clear trailer, neither times nor consumption will match between the tape's and collector's records. If either of these mismatches is serious, most computer processing routines will reject the whole tape. Thus, it is imperative that the cassette be removed before the clear trailer is reached and that the new tape's start-time not be logged unless the clear leader has been passed.⁹ The latter requirement would in most cases add significantly to the tape installation time. To avoid this problem, the Los Angeles Project made sure that all cassettes were wound past the leader before they were issued to the meter readers.¹⁰

Magnetic tape metering imposes certain other constraints on the planning of data collection that multidial metering does not. If, for any reason, the multidial meter cannot be read on schedule, as, for example, during a strike, there is no risk of data loss as a consequence of reading it even several billing periods late. Collection of tapes from magnetic meters, on the other hand, must follow a much more rigid schedule, since the end of the tape means the end of the record. Of course, this problem can be mitigated by use of tape-drive speeds that give a capacity

⁸Edmond Demonstration Project Progress Report, November, 1977.

⁹Documentation and Review of Los Angeles Demonstration Project's Data Collection and Editing Procedures. (no date)

¹⁰Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

well in excess of the billing period. Billing periods shorter than a month are infeasible for many reasons, while tape capacities much greater than 90 days are impractical because re-gearing the tape-drives to such low speeds would require re-design of the recorder. Thus, a limit exists to the excess capacity of the magnetic tape over the billing period, a limit that does not exist on the capacity of the multidual meter. This means that the operation of a magnetic tape metering system must have more precise scheduling and more extensive reserve data collection capacity than is needed in multidual metering.

In cases of exceptionally prolonged severe weather, there may be nothing to be done about the time limits imposed by tape capacity. Some parts of the Dayton Power and Light service area were so badly snowed in during the winter of 1976-1977 that tapes there simply could not be collected before they ran out.¹¹

Another special constraint on planning due to magnetic metering is the complete infeasibility of having customers collect data in unusual circumstances. This is a common practice with ordinary, single-dial metering, and could be applied to multidual metering. The error rate would probably be somewhat greater in the latter case, but even this difference could be minimized by careful design of the data forms. Having customers obtain, pull, and install magnetic tape cassettes is probably out of the question. Thus, extraordinary circumstances that could otherwise be dealt with by having the customer read the meter must be handled somehow by utility personnel.

DATA HANDLING FROM METER TO BILL PREPARATION

In multidual TOD metering, little more than mere transportation occurs between collection of data and the start of billing procedures. For present purposes, this kind of metering occupies a "zero" position on the data-handling dimension. The reason for including the dimension at all is that magnetic tape metering

¹¹Ohio Demonstration Project Product User's Guide. (no date)

presents a special complication at this juncture.

Because the immediate output of magnetic tape meters can be used for no purpose until it has been played back and converted into some legible form, computing equipment that would otherwise be associated with the billing phase of operations actually becomes an integral part of metering operations. In a sense, the magnetic tape meter is not read at the service entrance at all but in a central location with the use of a special-purpose computer, called a tape translator, which operates in the following general way: The tape to be translated has at least two channels--for purposes of this exposition we may assume that it has only two--a time-reference channel and a data channel. The time-reference channel contains evenly spaced pulses (usually at 5-minute, 15-minute, 30-minute or 60-minute intervals) that have been laid down by a clock-governed circuit in the recording meter. The data channel contains pulses that have been laid down by a recording meter circuit that responds to revolutions of the watthour meter disk. The essential job of the tape translator is to count the number of data pulses in each interval flanked by time pulses. The grand total of all the data pulses from one end of the tape to the other measures the total kilowatt hours consumed during the billing period. The translator can be programmed to take sub-totals of data pulses over pre-selected subsets of time intervals which correspond to different tariff periods in each day of the billing period. The translator can also be programmed to locate the time interval containing the largest number of data pulses. This measures a customer's peak demand for the billing period. The customer's coincident peak demand can be found by having the translator retrieve the number of pulses within the interval or intervals corresponding to the system's peak of each day and selecting from that subset of intervals the day yielding the largest number of data pulses. Thus, the translator program incorporates the utility's rate structure, and by change of program this basic hardware system can be applied to any practicable rate structure.

Malfunctions of the tape translator are as serious an impairment of the process from metering to billing as are malfunctions of the magnetic meters. More often than not the effect of a translator malfunction is more widespread because if the translator is inoperative for a sufficiently long time, the processing of tapes from all meters can be affected. For example, the Puerto Rico Project had difficulties with one or both of their translators throughout August and September of 1978 and did not restore both to normal operations until the end of October. This delayed the processing of all the data collected during that time.¹²

The basic translation routine will not always prepare magnetic tape data adequately for billing purposes. Post-translation editing procedures are often required to deal with distortions in both time and consumption data due to power outages, temperature related expansion or contraction of magnetic tape, differences in tape drive speed between the meter and the playback equipment and errors on the part of tape collectors. Problems due to power outage, tape speed variance and temperature effects are discussed more specifically in appropriate sections of this chapter. For the present it is sufficient to point out that most uses of magnetic tape data require skilled operations beyond the translation stage but before billing begins. A potentially serious consequence of this is that the whole process, from collection to the start of billing, had an added vulnerability to disruption by labor disputes during a strike in early 1977. Management personnel at Dayton Power and Light were able to collect the meter tapes on schedule, but editing of the data came to a halt and TOD customers had to be billed on regular rates.¹³ This illustrates the crucial dependence of proper billing on the "cleaning up" of raw tape data--a service that can be

¹² Puerto Rico Demonstration Project Progress Report, October, 1978.

¹³ Ohio Demonstration Project Product User's Guide. (no date)

provided only by specialists.

PREVENTION AND CORRECTION OF MALFUNCTIONS

Multidial watthour meters with clock-controlled switching of the dials are closely related to the single-dial meter that has been the service standard for decades. Their basic consumption-measuring mechanism is similar to its simplicity and reliability. Clock-controlled switching, too, is relatively simple technology, made reliable during a long and diverse history of application. However, all three Projects that used multidial metering experienced some malfunctions of their equipment. The most frequent problems in every case involved the time switches that shifted the consumption record from register to register. The Vermont Project found most of its two-dial meter defects in the motors that drive the clocks.¹⁴ The Arizona Project experienced problems with the timing equipment in general.¹⁵ In the Edmond Project certain lever-actuating pins on a rotating cam in the time switch were either missing or loose so that operation of the mechanism eventually dislodged them. There were such defects in six to eight of the 330 two-dial meters.¹⁶ The result of all these defects amounts to a failure of the register shift: all consumption after the malfunction is recorded on one dial only.

It is noteworthy that most of the multidial meter malfunctions were in a component not present in single-dial meters. Multidial TOD metering requires more components and more functional links from line power to dial than single-dial metering. And this can only mean a greater vulnerability to malfunction in the former than the latter, even if all the components of the multidial meter were as fail-safe as those of the single-dial

¹⁴Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980.

¹⁵Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

¹⁶Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980.

meter.

Chart 2 displays the major functional ingredients of single- and multidial metering. Each solid arrow indicates that correct operation of the component to which it points depends upon correct operation of the component where it originates. The dashed arrow from line power to carryover, in multidial metering, indicates that operation of carryover depends upon failure of line power. Branching arrows count as single functional links. First to be noted is that, while single-dial metering comprises only two functional links (one from line power to disk-and-stator and one from disk to dial), multidial metering comprises a minimum of four (link A from line power to both disk-and-stator and time control, link B from disk to total kwh dial and register shift, link C from register shift to the remaining dials, and link D from time control to register shift). The presence of carryover adds two more functional links, F, whereby the carryover is activated by failure of line power, and E, the correction of time control to register shift. Thus the multidial meter has at least twice--and with carryover three times--as many areas of potential malfunction as the single-dial meter.

The table accompanying Chart 2 presents typical causes of failure of each link in the multidial meter functional diagram, the results of each failure, and how each failure is to be prevented or corrected. Where examples of a particular malfunction occurred in the Projects they are noted.

It might be useful for the multidial TOD meter reader to perform some spot checks of proper meter functioning since, after all, the multidial TOD meter does have a greater vulnerability to malfunction than does the standard single-dial watthour meter. The subcontractor to the Edmond Demonstration Project responsible for testing and maintenance of their meters reports having "visually inspected" the dual-register meters for "proper operation of time-dial motors, proper register switching times and proper direction of rotation of meter disks."¹⁷ Insofar as

¹⁷ Edmond Demonstration Project Progress Report, May, 1978.

CHART 2

FUNCTIONAL COMPONENTS AND RELATIONSHIPS, SINGLE-DIAL AND MULTIDIAL METERING

1-DIAL WATTHOUR METER

MULTIDIAL TOD WATTHOUR METER

TABLE 3

MULTIDIAL METER MALFUNCTIONS

Failure of Link:	Typically Caused by:	Results in:	Prevention/Correction Steps	Remarks
A	Power outage	Stopped metering, no error in total kwh. Stopped time control unless carryover present and activated.	Not a metering responsibility.	
B	Mechanical/electrical failure in disk-and-stator.	Stopped metering, with subsequent consumption unrecorded.	Prevention mainly through design and quality control in manufacture; pre-installation test. Correction by shop repair or replacement.	A rare malfunction.
C	Shift-operating circuitry failure; mechanical defect in shift itself.	Either all consumption recorded on one dial only or no consumption recorded. (If total kwh dial present, its record is correct.)	As in failure of link B. Simple circuitry failure could probably be repaired in field.	6-8 Edmond Project meters recorded all consumption on one dial only. These malfunctions could have been of this type.
D	Electrical/mechanical failure in time control; failure of link E or F during outage.	Stopped register shift. All consumption recorded on one dial.	As in failure of link B.	The Edmond Project malfunction could have been of this type.
E	Carryover absent; circuit failure; dead or weak battery; failure of link F.	Cutage stops time control. Resumption of service causes time error, requiring manual reset of time control.	As in failure of link B. Prevention by regular check and replacement of battery. Prompt reset to minimize error.	Arizona Project did not use carryover; reset some 15% of meters per month. Edmond Project also had to reset meters.
F	Failure of relay to engage carryover when line power is lost.	Same effect as failure of link E.	As in failure of link B. Carryover could be activated as field test for correct operation.	Not reported by Projects. Mr. David Goeckler, Meter Div., K.C. Power & Light, reports this as having occurred in some meters. (Personal communication)

Source: Compiled from Electric Utility Demonstration Project reports and documents and interviews, 1975-1980

these rough checks for gross malfunction do not require disassembly of the meter or the use of test apparatus, meter readers could be instructed in them and scheduled to carry them out on rotating subsets of the meters on their routes. In any event, the meter reader should at least make sure that the time control for register switching is on schedule (e.g. not lagging or leading because of an uncorrected power outage.) The time clocks on the General Electric meters used in the Edmond and Vermont Projects could be easily reset by the reader, without opening the meter case.¹⁸ The Arizona Project's use of indicator lights (one light on during shoulder period, two lights during peak period, no light during off-peak) afforded a simple check of gross timing errors.¹⁹

The typical magnetic tape demand recording system incurs a much heavier obligation to operation and maintenance than does multidiurnal metering. To begin with, the magnetic tape metering equipment at the service entrance comprises some of the same basic components found in a multidiurnal meter--namely a watthour meter and a clock. The tape recorder requires both of these in order to record energy consumption along with time-reference signals. Thus, much of what can develop problems in a multidiurnal meter is there to develop problems in the magnetic tape meter. But the magnetic tape meter also contains a pulse-initiating device that translates revolutions of the watthour meter disk into electrical signals, circuitry that transfers these signals to a magnetic recording head, and an electric motor and gear-train to move the magnetic tape.²⁰ Each of these components provides additional possibilities of malfunction.

The incidence of defective magnetic tape meters varies con-

¹⁸ Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980.

¹⁹ Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

²⁰ A single motor drives both the tape and the time pulse generator (clock).

siderably from Project to Project. The Edmond Project reported only one outright meter defect, all other problems associated with this type of meter were due to tape exchange errors or improper installation of the meter itself.²¹ The Puerto Rico Demonstration Project had to have 58 meters repaired by late July, 1979, mainly because of faults in the tape-drive motor.²² Eleven magnetic tape meters installed by BREMC in the North Carolina Project required repair for unspecified reasons. Three of these were repaired in the field and eight had to be brought to the meter shop.²³ Carolina Power and Light, the other utility participating in the North Carolina Project, experienced few, if any, malfunctions of their metering equipment.²⁴ The first pulse-initiating devices used by the Arkansas Project were of a mechanical type. These failed at nearly a 30 percent incidence in some meter groups because of carbon build-up on certain electrical mechanical contacts. After the first few months of the Project, these mechanical pulse-initiators were replaced by solid state devices.²⁵ The Wisconsin Project experienced a problem with one component of one type of meter that led to incorrect readings for low-usage customers. When pulses passed through the initiator circuitry with low enough frequency, the intermittent character of the current corroded a mechanical contact. The build-up of corrosion over time would finally block all current. This was repaired by the utility. They also had to replace many tape drive motors.²⁶ The Ohio Project did

²¹Edmond Demonstration Project Progress Report, March, 1978.

²²Summary, Puerto Rico Demonstration Project Review Meeting, July 19-20, 1979.

²³North Carolina Demonstration Project Progress Report, November, 1977.

²⁴Telephone interview, Billy Harborough, Carolina Power and Light Co., April, 1980.

²⁵Arkansas Demonstration Project Final Report. (no date).

²⁶Telephone interview, Richard James, Wisconsin Public Service Corp., April, 1980.

not report the frequencies of specific meter defects but did refer to considerable data problems due to failures of the tape drive, the clock motor and the time impulse generator in their recording meters. They also referred to a kind of recorder malfunction that shows zero consumption when, in fact, consumption is greater than zero.²⁷

Chart 3 presents the functional organization of magnetic tape metering according to the same scheme as Chart 2, for multidial metering. Its accompanying table lists functional link failures, their typical causes and effects, maintenance and correction steps and instances of malfunctions from the Projects.

The very substantial increase in complexity from multidial to magnetic tape meters is evident on comparing Charts 2 and 3. But equally important to maintenance issues is the fact that some of the functional links in magnetic tape metering are intrinsically weaker than any in multidial metering. Magnetic tape is more fragile and dimensionally unstable than the typical component of the multidial meter. The Ohio Project attributed at least 80 percent of its magnetic metering problems to the tape itself (rippled tape, defective oxide coat).²⁸ These tapes can be damaged by defective operation of the magnetic recorder itself, as occurred when the Los Angeles Demonstration Project attempted a modification of the tape drive mechanism on a suggestion from the vendor, Sangamo Weston Corporation. This modification was intended to overcome the problem mentioned above of an excessively thick coating on some of the tapes that had been supplied.²⁹

The mylar base of magnetic recording tape has good dimensional stability under temperature change relative to many other similar materials. However, extremes of cold occur in many

²⁷Ohio Demonstration Project Product User's Guide. (no date)

²⁸Telephone interview, Henry Duckworth, Dayton Power and Light Co., April, 1980.

²⁹Documentation and Review of Los Angeles Demonstration Project's Data Collection and Editing Procedures. (no date)

TABLE 4

MAGNETIC TAPE METER MALFUNCTIONS

Failure of Link:	Typically Caused by:	Results in:	Prevention/Correction Steps	Remarks
A	Power outage.	Stopped meter disk; time-pulse generator, tape drive require separate power source to continue.	Not a metering responsibility	
B	Mechanical/electrical failure in disk-and-stator.	Stopped kwh dial and pulse initiator; record looks like zero consumption or outage.	Prevention is mainly through design and manufacturing quality control; pre-installation test. For correction, either shop repair or replacement.	A rare malfunction.
C	Carbon build-up on contacts (if mechanical type pulse initiator), other parts failure.	Loss of data pulses, spuriously low record of consumption.	Prevention by regular cleaning of contacts, replacement of mechanical pulse initiator with solid state pulse initiator.	Nearly 30% of some Arkansas Project meter groups failed because of this defect.
D	Oxide build-up on recording head; circuit failure.	Loss of record, both time and data pulses.	Regular clearing of recording head.	Wisconsin and Puerto Rico Projects required this once a month.
E	Bad tape; thermal shrinkage/expansion; tape breakage; tape change error	Any of several degradations of data, from outright loss to a small mismatch of times.	Prevention by quality-control over manufacturing of tapes; protection of meter from temperature extremes; correction by editing (if correctable, retraining in case of tape change error).	Los Angeles Project had broken, perforated tapes; Wisconsin, Puerto Rico Projects found thermal effects on tape length; Wisconsin Project had tapes break from extreme cold; Edmond Project lost data from 31 meters because of tape change error.

(continued)

TABLE 4

MAGNETIC TAPE METER MALFUNCTIONS (continued)

Failure of Link:	Typically Caused by:	Results in:	Prevention/Correction Steps	Remarks
F	Mechanical/electrical failure of time pulse generator.	Loss of time pulses.	Prevention is mainly through design and manufacturing quality control; pre-installation test. Correction is by shop or manufacturer repair.	
G	Tape jam, undrivable tape, motor failure.	Loss of subsequent record.	As in failure of link F; some tape jams can be hand-corrected in field.	Puerto Rico Project required replacements of magnetic tape recorders with defective tape drive motors.
H	Carryover not installed; dead or weak battery; circuit failure; failure of link I.	Outage stops time-pulse generator, tape drive; resumption of service sets up a time error.	Install carryover, check battery, replace if weak; without carryover, correct tape for outage by editing routine; obtain exact times of outages.	Los Angeles Project did not use carryover and lacked exact data on times of outages; had to treat multiple outages as single outage, with loss of kwh data. Puerto Rico Project installed carryovers, but lost some time-keeping because of extra long, frequent outages, dead or weak batteries.
I	Carryover activating relay failure.	As in failure of link H.	Prevention mainly through design and manufacturing quality control; pre-installation test. Field repair unlikely.	Not reported by Projects. Mr. David Goekler, Meter Div., K.C.Power & Light, reports this malfunction in a certain lot of magnetic tape meters. (Personal communication)

Source: Compiled from Electric Utility Demonstration Project reports and documents and interviews, 1975-1980.

parts of the United States that will cause mylar-based tape to shrink significantly below its indoor temperature length. When a tape that has been recorded at such extremely low temperatures is brought indoors for playback, it lengthens, and the locations of the magnetic pulses are spread apart. When this tape is played back, the time period intervals appear longer than normal. The Wisconsin Demonstration Project found this to be a major problem in their data collection and editing procedures. It contributed significantly to their ten percent rate of records unusable for billing.³⁰ Tapes not only changed length but broke as well due to the extreme cold, and it was decided early in the Wisconsin Project that heating devices would have to be installed in the meters.³¹ In many northern localities meter heaters must be regarded as an integral component of magnetic tape metering.

The time distortions caused by temperature effects on the tape, as well as by differences in speed between the meter tape drive and the playback tape drive, necessitate the use of fairly sophisticated editing programs in the preparation of billing and analysis data. Largely because of such problems, the Wisconsin Project's software development took an estimated two to three person-years of computer programming.³² The main reason that time distortions are a problem is that translation routines actually measure the intervals between time pulses, keeping a moving average of the past few intervals in order to insert simulated pulses should the next pulse be missing from the record. If the translator is reading a time-distorted tape, it could under some circumstances simulate missing time pulses when, in fact, all pulses are present, thus causing there to be too many

³⁰Minutes of Wisconsin Electric Pricing Project Meeting, July 1, 1977.

³¹Wisconsin Demonstration Project Progress Report, April, 1977.

³²Wisconsin Public Service Corporation TOD Pricing Experiment, Chronological Summary. (no date)

intervals on the translated record.³³

High temperatures can have a much worse effect on tape data quality. Direct sunlight on the box containing the recorder can raise its internal temperature to as much as 160° F. At such temperatures, the tape can stretch and the oxide coat soften and smear, completely wiping out the recorded pulses. The Puerto Rico and Rhode Island Projects both reported data losses due to this effect.³⁴

Like any magnetic tape recorder, the magnetic tape meter is vulnerable to build-up of oxide deposits on the recording head. Pulses missing from the data channel are the most common consequence of this defect. Also, even a very small particle of dirt between the tape and the head can cause a sufficient gap to prevent recording.³⁵ Thus, regular cleaning of the recording head is part of necessary maintenance. The Wisconsin Project considered it mandatory to perform this service once a month.³⁶ Applying this recommendation to the typical demonstration project indicates that head cleaning should occur at least as often as the tapes are collected from the meters. The Projects that used magnetic tape meters did have their tape collectors clean the heads at each tape change, except for the Los Angeles Project where the heads were cleaned every third visit to the meter (twice a year). This project attributed no data loss to oxide or dirt problems, citing the very slow speed of the tape in a 90-day cassette as a possible reason for lack of oxide build-up.³⁷

³³ Documentation and Review of the Los Angeles Demonstration Project's Data Collection and Editing Procedures. (no date)

³⁴ Telephone interview, Lewis Bailey, Blackstone Valley Electric Co., April, 1980 and Osvaldo Goyco, Puerto Rico Electric Power Authority, remarks at Electric Rate Demonstration Conference Workshop, April, 1980.

³⁵ Telephone interview, Henry Duckworth, Dayton Power and Light Co., April, 1980.

³⁶ Wisconsin Public Service Corporation TOD Pricing Experiment, Chronological Summary. (no date)

³⁷ Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

As tapes are used again and again they become increasingly subject to recording failures. One cause of the translator's having to simulate "missing" pulses is that old tapes with worn oxide coatings can sometimes record pulses only very faintly--too faintly to be picked up by the playback head in the translator.³⁸ The apparent consensus among the utilities participating in the Projects is that no hard-and-fast rule covers the useful life of magnetic tapes, as their rate of wear and tear depends so heavily on the operating conditions at each location. A cartridge used in a residential meter might last two years without trouble; a cartridge used at a sawmill could be destroyed by wood dust in six months.³⁹

A NOTE ON PAPER CHART DEMAND RECORDERS

As has been mentioned elsewhere in this Report, one Project used General Electric G-9 Chart Demand Recorders, instead of magnetic tape recorders, for load analysis purposes. The Vermont Project chose these devices for their relatively low price, for their ability to provide a "hard copy" and because the charts could be viewed by the customer as they were being recorded.⁴⁰ The circular charts had a 16-day capacity, but were changed every 14 days to insure against run-out.⁴¹ Analog records present some accuracy problems in transcription not encountered in digital records. Green Mountain Power developed a chart-reading device that provided precisely controlled chart movement, magnification and special illumination.⁴² Even with this assistance, however, the utility found it helpful to rotate different personnel through the chart-reading task in order to reduce errors

³⁸Telephone interview, David Bryant, Arkansas Power and Light Co., April, 1980.

³⁹Ibid.

⁴⁰Vermont Demonstration Project Progress Report, May, 1975.

⁴¹Ibid.

⁴²Ibid.

and increase speed.⁴³

The very sharp limit to time-capacity of circular charts, the trade-off between capacity and legibility, and the labor intensive character of data-handling, all would tend to discourage the use of chart demand recorders as billing meters or even as load survey devices on a large scale.

OUTAGE PROBLEMS

TOD meters normally use power from the distribution system to keep the time. Line power runs the register-switching clock in multidual meters, and the time-pulse generators and tape drive in magnetic tape meters. When power fails in the distribution system, these normal timekeeping functions stop. In the absence of any back-up power supply to the mechanisms of time-keeping, when service is resumed, the record continues with a time error. Unless the duration of the outage were exactly 24 hours, or an integral multiple of 24 hours, this error would have to be corrected, or some consumption must be assigned to the wrong tariff period.

In multidual metering, it is logically possible to reset the switching clock after the end of outage. But this requires a visit by personnel to each affected point. In the case of a large-scale outage, the numbers of persons required to achieve reset at all points within a reasonable time after outage could easily make this option infeasible. Time is important here because serious equity problems arise whenever one meter is reset much later than another. Even in the absence of large-scale outages, local outages are sufficiently frequent in any fair-sized system to require dedication of standby personnel to meter resets.

None of the Projects using multidual meters provided battery carryover. All relied on manual resetting of their multidual meters to correct outage time errors. The Edmond Project kept a standby meter reader available on a 24-hour basis to reset its

⁴³Ibid.

meters. Each reader worked 200 hours per month: 40 hours on regular reading duty and 160 on this standby reset duty. Because all the meter readers on the Edmond Project were special part-time personnel, paid only \$200 per month irrespective of the difference between regular duty and standby reset duty, the overall cost of using manual reset was far less than would have been the cost of supplying battery carryover to each of the project meters.⁴⁴ The Arizona Project chose the manual reset method to explore its cost effectiveness. By the end of the tests they had decided that it would have been better to install battery-powered carryover capability, as some 15 percent of the meters, on average, had to be reset each month. The small size (40 residences) of the Vermont TOD study, plus the low outage rate (approximately one per customer in the whole test period in urban areas; three to four per year in rural areas) kept their lack of carryover capacity from becoming a serious problem.⁴⁶

Because of the large variation in outage incidence between the projects using multidual meters, it is difficult to assess the cost effectiveness of battery carryover versus manual reset on the basis of the Projects alone, but battery-powered carryover might well be cost effective even with moderate outage frequency in a small system. Whatever the incidence of outage requiring manual reset, the utility must maintain the capacity for prompt reset around the clock. This means personnel on duty at all hours and in many cases this, in turn, would mean personnel drawing overtime pay after regular business hours. The frequency of outage and the size of the system determine how many such personnel need be employed, not whether or when they should be.

Manual reset after outage has no place in magnetic tape metering. Time is recorded not as a sequence of clock readings

⁴⁴Edmond Distribution Project request for additional funds, August 12, 1977.

⁴⁵Arizona Demonstration Project Final Report, February 1978.

⁴⁶Telephone interview, Porter Cleveland, Green Mountain Power Corp., April 1980.

but as the number of pulses from the start end of the tape. Should the time-pulse mechanism and tape drive motor stop and then start up again, the sequence of time pulses will continue as if nothing had happened. Only when the tape translation process shows the number of time pulses to be less than that required to make up the logged start/pull interval for the tape does it become evident that the meter has stopped recording the time during the billing period.⁴⁷ For example, suppose that a utility used 15 minute demand intervals and a 30-day billing period. There are 2880 fifteen-minute intervals in 30 days. Thus, if the reader has accurately logged the start and pull times of the tape as exactly 30 days apart, the tape translator should read off at least 2880 pulses from the time channel of the tape. If the pulse count exceeds 2881 or 2882, it may be assumed that the reader erred in recording either the start or pull time, since significant speeding up of the time-pulse mechanism is a most improbable malfunction. The number of pulses less than this actually read off is a measure of the total outage time. Thus if, for example, the tape translator counted only 2860 time pulses from end to end, this would indicate a total outage of some five hours. But in order to attribute a shortfall of time pulses to one or more power outages, it must be the case that the total kwh read from the data channel of the tape agrees fairly closely with the total kwh read off the watthour meter dial by the meter reader. If it does not, then a number of failures--electrical, mechanical or human--might be responsible, but in any case the tape is useless. A power outage will, of course, invariably stop the timing mechanism, the tape drive, and the revolutions of the watthour meter disk altogether, and only under such conditions will the total kwh be the same on the

⁴⁷ There are time dials on magnetic tape meters that indicate the synchrony of the time pulse generator with standard clocks. Tape collectors can reset the meter clock, should they detect a discrepancy, but such discrepancies could also indicate a malfunction rather than an outage.

dial and in the data channel of the tape, while the meter reader's time and the "tape" time differ.

Unfortunately, the determination that at least the outage has occurred is not sufficient to assure valid assignment of energy consumption to tariff periods. The distribution in time of the outages, as well as their durations, has a large effect on the percentage of consumption assigned to the wrong tariff period. For example, consider a two-period rate structure, with twelve hours on peak and twelve hours off peak. If there is a one-hour outage within the first tariff period of the billing cycle, then every shift of tariff thereafter will be one hour late, causing one-twelfth of all on-peak consumption to be counted as off-peak consumption, and one-twelfth of all off-peak consumption to be counted as on-peak consumption. One-sixth of the total is mispriced. If the one-hour outage occurs at the last tariff period of the billing cycle, only one-sixth of one-thirtieth ($1/180$) of the total kwh is mispriced. The later in the billing cycle that an outage of given length occurs, the less its effect on the total error of the record. By the same reasoning, once a first outage has occurred, the later that subsequent outages follow, the less their total impact.

A single outage during the billing period can be compensated for during editing of the tape if the meter has what is called a loss of potential capability, i.e. the ability actually to signal the commencement of a power outage on the tape. In that case, the total shortfall of the time pulses is taken as the duration of the outage, and since its start-time is known, the subsequent consumption record after resumption of service can be correctly divided into the different tariff periods. But if there are multiple outages within the billing period, all that can be determined from the tape is their number. The total shortfall of time pulses would have to be apportioned among them in order to determine their duration and the intervals between them. The information required for this can only be supplied independently of the tape data. In some of the Projects that did not use carryover, the participating utilities could determine

the times and durations of outages with sufficient accuracy from the records of their distribution sections or from interrogation of customers. Others found this difficult or impossible. The Ohio and Wisconsin Projects got satisfactory results from three methods;⁴⁸ the Arkansas Project had trouble determining just when some outages occurred in parts of their service area.⁴⁹ The Los Angeles Project had no independent time data on outages at all. Their meters had the loss of potential indication, so that the beginning of each outage was recorded, but multiple outages could not be distinguished in data processing from a single long outage. In this circumstance the later in the billing cycle that a second outage occurred, given a first outage, the worse its effect on the data, for all consumption data between the onset of the first outage and the termination of the last had to be sacrificed.⁵⁰ It is easy to see that two fifteen-minute outages, separated by, say, 50 days of the billing period, would effectively sacrifice the entire consumption record,

Magnetic meters, like multiradial meters, can be provided with battery-powered carryover to run the time-pulse generator and tape drive in the absence of line power. The problems of handling outages at translation and edit stages are certainly difficult enough to make this alternative appealing. However, carryover devices are neither cheap nor free of added operation and maintenance problems. They will typically add between \$60 and \$80 to the cost of each meter. Care must be taken that the battery have proper charge at the time of meter installation and the charge must be checked regularly--a duty that would naturally fall to the tape collector. The tape collector, likewise, would in most cases be responsible for the replacement of weak or dead

⁴⁸ Telephone interview, John Zulauf and Henry Duckworth, Dayton Power and Light Co., and Richard James, Wisconsin Public Service Corp., April, 1980.

⁴⁹ Telephone interview, David Bryant, Arkansas Power and Light Co., April, 1980.

⁵⁰ Documentation and Review of the Los Angeles Demonstration Project's Data Collection and Editing Procedures. (no date)

batteries. The incidence of this particular service should be fairly low because of the long shelf-life and duty-life of the batteries typically used in carryover,⁵¹ but it does represent some additional maintenance time and a further training requirement. That battery adequacy can be a serious problem is indicated by the Puerto Rico Project's experience, mentioned above, of some of their meters failing to carry the time-keeping functions over the prolonged and frequent outages that occurred during the strike against PRWRA. At least some of these failures were due to the installation of inadequately charged batteries in the carryovers. Nonetheless, the particular problems of outage-induced time error in magnetic tape metering, where there is no opportunity to correct for these by manual reset of a clock, actually make battery-powered carryover all but imperative in any large-scale application of magnetic tape meters. Having battery carryover would appear to make the loss-of-potential feature superfluous. However, without an indication of power interruption on the tape, there is no way to discriminate--from tape date alone--periods of zero consumption from power outages in which the carryover kept the time pulses coming and the tape moving.⁵²

A NOTE ON CENTRALLY CONTROLLED SWITCHING

An important possible alternative to both battery carryover and manual reset in multidial metering is remote control of register shift, either by radio signals or by signals transmitted over the distribution system lines. This technology is integral to centrally controlled load management. It, of course, entirely obviates all time error problems associated with power outages, since no meter in such a system depends upon line power for its

⁵¹Earlier models of carryover used gel-cell batteries, considerably many of which leaked around the terminals or even burst. (Reported in interviews by David Goeckler, Kansas City Power and Light Company and by David Bryant, Arkansas Power and Light, April 9, 1980.) Nickel-cadmium batteries, now in general use, are free of this problem.

⁵²Telephone interview, Earl Taylor, North East Utilities, April, 1980.

time-keeping functions. While none of the Projects used this technology in their TOD metering, the Ohio Project did give it careful consideration, partly because they were already committed to the use of radio control signals in a load management phase of their study.⁵³ Some discussion of the Ohio Project's experience with the radio control apparatus is pertinent here because, up to the point of application either to load control switches or to the register shifting apparatus in a TOD meter, the equipment and its operation are exactly the same. As has been mentioned above in the Acquisition and Installation section, nearly all of the radio controlled switches received from the vendor, Motorola Corporation, showed malfunctions on delivery and had to be returned for modification or repair.⁵⁴ There was a major breakdown in the radio control system on September 2, 1977. The telephone cable linking the central control station to the radio transmitter developed excessive noise which resulted in continuous transmission of signals. This, in turn, kept the air conditioners turned off.⁵⁵ Had such a breakdown occurred to a radio control system connected to multidial TOD meters its result would very likely have been to cause all consumption at the affected metering points to be recorded on one register only. Because in such a system each of relatively few transmission stations controls a great many metering points, malfunctions at the transmission end would have very widespread effects. By the end of March, 1977, some nine and a half months after the Ohio Project began its radio control interruptions of space conditioning units, some of the receivers were still not receiving the transmitted signals.⁵⁶

⁵³ Ohio Demonstration Project Progress Report, August, 1975.

⁵⁴ Ohio Demonstration Project Progress Report, September, 1975.

⁵⁵ Ohio Demonstration Project Progress Report, September, 1977.

⁵⁶ Letter, Government Technical Representative Christophersen to Robert Wayland, PUCO, April 13, 1977 (Summary of Ohio Project Review Meeting, March 31, 1977).

The Vermont Project also used central control in a load-shedding experiment. The switches on customers' hot-water heaters were controlled not by radio but by low-frequency modulations of the 60-hertz power itself, the so-called "ripple" system. The performance of this installation was for all purposes trouble-free, in marked contrast to Ohio's experience with radio control.⁵⁷ This difference in performance may be related to a marked difference in practical experience between the two technologies: while load control applications of radio signalling were still relatively new at the time of the Ohio Project, ripple control of load shedding had been used in Europe for some thirty years. The Vermont Project acquired its ripple system hardware and programming from a European vendor.⁵⁸

SUMMARY

Magnetic tape metering and multi-register metering differ significantly in four major aspects of operation and maintenance: 1) data collection, 2) data handling from meter to bill preparation, 3) prevention and correction of malfunctions, and 4) dealing with power outages. In each of these aspects, the operation and maintenance of magnetic tape metering are more complex and effortful than the operation and maintenance of multi-register metering.

All forms of TOD metering that use a local clock lose their timekeeping function during power outage, unless a reserve power source (battery carryover) is available. Multi-register meters without carryover must be reset manually. Tapes from magnetic tape meters without carryover lose time pulses during outage. Thus an uncorrected translation of such a tape will contain a variable misallocation of consumption data to tariff periods. Correction of these outage effects requires independent data on times, durations, and locations of outages.

⁵⁷There is no mention or problems with the ripple control system in the DOE file documents on the Vermont Project.

⁵⁸Vermont Demonstration Project Progress Report, May, 1975.

Multi-register meters can be controlled from a central station by way of radio, powerline, or telephone signals. This system allows register-shifting either to remain on schedule during an outage (in the cases of radio and telephone line control) or to be brought back on schedule immediately after outage (in the case of powerline control).

CHAPTER : CUSTOMER EXPERIENCES FIVE

INTRODUCTION

This chapter contains an examination and discussion of the experiences of customers as a result of TOD metering. The focus is on those experiences related to the meters per se as opposed to those associated with rates or being a part of the experiments. There were a number of these experiences in each of the projects, and this points to the fact that a change in metering affects the customers as well as the utility company.

The chapter examines the level and incidence of customer involvement in metering changes. This includes customer understanding of the metering equipment, their psychological reactions and the response of the utility to the reactions.

CUSTOMER UNDERSTANDING

Probably less prior consideration is given to customers' responses to the new metering than to any aspect of TOD rate implementation. This is understandable, given that customers have long been familiar with the single-dial watthour meter of traditional electricity pricing. Also, in the context of the Projects, the customers' attitudes toward the novel metering are partially embedded in their attitudes toward participation in the rate test, and are not always easy to consider separately.¹ Thus, questions of what customers think of multidual or magnetic tape meters and how well they function tend to take a back seat to the problems of acquiring, installing, maintaining and operating these meters. But if TOD pricing were to have the desirable effect of making customers more conscious of how much energy they consume and when they consume it, then it is to be expected that the customers' interest in the meters themselves will increase proportionally.

¹Telephone interview, Richard James, Wisconsin Public Service Corp., April, 1980.

Perhaps the most important difference between multidial and magnetic tape meters, from the standpoint of customer acceptance and cooperation, is that customers can read the former themselves but not the latter. If magnetic tape is the billing basis, then the customer has no way of seeing the direct record of time-differentiated consumption on which the bill is based. This consideration was one important factor in the decision of the Arizona Project to use multidial meters rather than magnetic tape meters.² Customers in the Ohio Project actually suggested that meters be used that they could read, such as a digital display meter, rather than the tape recorders that were used.³ Customers in the Vermont Project greatly appreciated the visible charts of the G-9 demand recorders, and it was the feeling of project personnel that this feature significantly promoted customer cooperation.⁴

A good portion of adverse reaction to TOD metering equipment seems to stem from the customer's ignorance of what the equipment is supposed to do and how it does it. Such ignorance can reach surprising levels: in the Edmond Project, despite explicit information to the customers and the presence of a different type of meter, only 60 percent of test customers interviewed at the close of the study manifested knowledge that they had been on a TOD rate.⁵ Customers as a group are not used to knowing anything about rate structure, let alone anything about the relation of metering to rate structure. Consequently, some of their misgivings about their new meters can appear rather improbable from

²Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

³Telephone interview, Mack Wathen, Ohio Public Utilities Commission, April, 1980.

⁴Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980.

⁵Dr. William Crano, "Evaluating Demonstration Customers' Attitudes Toward Time-of-Use Rates," Electric Rate Demonstration Conference, Denver, Colorado, April 13, 1980.

the utility's point of view. In the Rhode Island Project, there were cases in which customers became alarmed at seeing an indicator lamp burning on their magnetic tape meter at night, as this somehow convinced them that the meter was itself increasing their electric bills.⁶ One or two Arizona Project customers expressed a dislike of the tariff-period indicating lamps going on and off and requested their removal. Arizona Public Service complied without asking for explanations,⁷ and so it is not known what the basis of these objections was, but lack of clear understanding of the indicator lamp function very likely played a role. That customers will not always understand what tariff-period indicators mean, even after explicit information is given them, is illustrated by the numerous inquiries about these lamps to the Los Angeles Department of Water and Power after they replaced their experimental magnetic tape recorders with two-dial meters.⁸ The Connecticut project received quite a number of calls from customers alarmed by the loud "hum" emitted by their carryover devices during power outages.⁹ This case points out the generalized sensitivity of customers to any anomalous behavior of unfamiliar metering equipment. The noise made by the carryover during operation will, of course, seem entirely normal to meter department personnel, and there is little reason to expect them to realize that to many customers it will appear decidedly abnormal.

Perhaps the most telling of all the examples of the lack of customer understanding of metering was in Arizona where a customer called to tell the utility that they could remove one of

⁶Telephone interview, Lewis Bailey, Blackstone Valley Electric Co., April, 1980.

⁷Telephone interview, Paul Hart, Arizona Public Service CO., April, 1980.

⁸Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

⁹Telephone interview, Jacklyne Smith, California Public Utilities Commission, April, 1980.

the meters because a son had moved out of the residence. In Arizona, it might be recalled, a two meter configuration in a single trough was installed. Apparently the customer believed that a separate meter was used for each resident in a single family dwelling.¹⁰

CUSTOMER ACCEPTANCE

Customers may have aesthetic concerns associated with installation of new metering equipment, especially magnetic tape meters. Some Wisconsin Project customers objected to the appearance of the meter/recorder package itself, probably because of its bulk. The fairly large two-meter compound of the Arizona Project also met with some aesthetic criticism from customers.¹¹ Beyond the appearance of the meter, there is the question of damage to house siding or finished interior work if the equipment should be installed indoors. In some circumstances the recorder box must be installed to one side of the watthour meter rather than below it. Then it is advisable to pin the recorder to the wall, so as to nullify the torque its weight imposes on the meter-socket junction.¹² Owners of houses with aluminum siding might be particularly concerned about the necessary puncturing of the exterior wall.¹³ The Ohio Project staff required meter installers to take special care not to inflict any damage on interior surfaces when installing metering equipment. In several cases the three-meter-plus-recorder ensemble had to be installed

¹⁰Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

¹¹Telephone interview, Paul Hart, Arizona Public Service Co., April, 1980.

¹²Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980.

¹³Telephone interview, Richard James, Wisconsin Public Service Corp., April, 1980.

in finished living quarters, where any marking, defacing, etc., must be treated with all seriousness.¹⁴

Indoor installation of meters can have an effect on customer acceptance. A meter that requires utility personnel to enter the customer's home is, from the customer's viewpoint, a radically different approach to selling electricity from the traditional methods. In some Projects, indoor installation was unavoidable, at least in a substantial number of residences.

The Ohio Project separately metered certain appliances in TOD rate test homes. This made indoor installation of all metering equipment far more practical than running cables from the load component meters to an externally mounted recorder.¹⁵ The Project personnel felt that this indoor installation had a definite negative effect on customer acceptance of the meters. Vermont's G-9 chart recorders, as has already been mentioned, had to be installed indoors because of their unreliability at subzero temperatures. A requirement for participation in the Project was that the customer must provide the utility with a house key for the chart collectors.¹⁶ While this gave the Vermont Project no particular difficulty, it seems most likely that there would be many customer acceptance problems with such a requirement in a large scale, nonvoluntary implementation of TOU pricing.

The Puerto Rico Project encountered the equivalent of an indoor installation problem in the location of the meter bases within recesses covered by iron grillwork. To unlock these coverings, meter readers had to get a key from the residents. Some 25% of experimental residences had to be visited in the

¹⁴Telephone interview, John Zulauf, Dayton Power and Light Co., April, 1980.

¹⁵Telephone interview, John Zulauf, Dayton Power and Light Co., April, 1980.

¹⁶Telephone interview, Porter Cleveland, Green Mountain Power Corp., April, 1980.

evening for tape collection because of this factor, where the residents were not at home during regular business hours.¹⁷

The Los Angeles Project found in several cases that meters for individual apartments were placed together in a single locked storage room, usually in the basement of the apartment building. Customers on the experimental rates and non-experimental customers were in the same building, so that the meter room had to be visited twice, once by regular meter readers and once by the magnetic tape collectors, each billing period. Landlords objected, sometimes rather forcibly, to having to unlock the meter room so frequently. Some older single-family residences in the Los Angeles Project's service area had indoor service entrances because of the enclosure of their rear porches after the original meters had been installed there. Two customers with indoor service entrances refused the new metering because they did not want tape recorders inside their residence. The impression of the Los Angeles Project staff was that these customers suspected that their conversations might be recorded by the devices.¹⁸ Peculiar responses such as this probably have much to do with the customers' understanding of the new metering equipment.

CUSTOMER REACTIONS

Some customers reacted to the new meters by blaming the meter for higher bills. In both Rhode Island and Wisconsin customers were concerned that the extra current required to operate the magnetic tape meter was being charged to them.¹⁹ When this occurred it was explained that the utility paid for the electricity required to run the meter. This seemed to satisfy most customers, but some continued to insist that the meters "had gone wild." Edmond Project customers who made such complaints were offered a meter test on their premises. A portable

¹⁷Minutes, Puerto Rico Demonstration Project Review Meeting, July 19-20, 1979.

¹⁸Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

¹⁹Telephone interviews, Lewis Bailey, Blackstone Valley Electric Co., and Richard James, Wisconsin Public Service Corp., April, 1980.

standard meter was brought to the residence and the test performed in the customer's presence.²⁰ This is a very worthwhile procedure, as mere explanation is often not enough to satisfy a customer already convinced that his or her bills are being increased by the meter itself.²¹

One customer had a fire at her home shortly after the meter had been installed. The meter was blamed for starting the fire and a thorough inspection was made by the local utility. It was determined that the fire was not caused by the meter but by faulty wiring. The customer, however, was not convinced. The engineering consulting firm employed by the project was asked to make an inspection. They did, with the same results as the first. The customer remained unconvinced and accused the parties of being in cahoots.²²

Another area of customer reaction was outright hostility. In Arkansas one customer brandished a shotgun and threatened to shoot the reader/installer. Though it was a mandatory project the meter was removed.²³ Not quite as extreme a reaction took place in Wisconsin. One apparently irate customer chained a vicious dog in sufficiently close proximity to the meter and the tape changer could not pick up the tape without risk to his person. If it had been a "standard" meter it could have been read with a telescope, but since the tape must be picked up and the meter serviced (about 10-15 minutes) the customer tactic

²⁰Telephone interview, Upton Henderson, Central State University, April, 1980.

²¹Telephone interview, Richard James, Wisconsin Public Service Corp., April, 1980.

²²Telephone interviews, Upton Henderson, Central State University; Neil Dikeman, Oklahoma University; and Charles Massey, C. H. Guernsey & Co., April, 1980.

²³Arkansas Demonstration Project Progress Report, December, 1975.

created a problem.²⁴ Dogs, friendly or otherwise, were encountered in the Los Angeles project also. However, the customer was not hostile and arrangements to pick up the tape were made.²⁵ In the Edmond project, where multidual meters were used, some had to be read from a distance with the aid of a telescope or binocular.²⁶

Some customers did not try to prevent the meter from being read by threatening the reader. They simply assaulted the meter. One project reported that some two or three meters were broken and looked as though they had been struck with a baseball bat or some other club.²⁷ Others attempted to steal the meters.²⁸

Still other customers were simply curious about the meters and asked questions about their operation.²⁹ One customer is reported to have spent rather considerable amounts of time just watching the magnetic tape meter working.³⁰

A final customer reaction was what might be called the "singling out" phenomenon. There were reports from both Wisconsin and Rhode Island that customers wanted to know "Why me?" They seemed concerned as to why they had a different meter from

²⁴Dr. Rodney Stevenson "Establishing Objectives for Residential Load Research," presented at the Electric Rate Demonstration Conference, Denver, Colorado, April, 1980.

²⁵Telephone interview, Dennis Whitney, Los Angeles Department of Water and Power, April, 1980.

²⁶Telephone interviews, Upton Henderson, Central State University and Neil Dikeman, Oklahoma University, April, 1980.

²⁷Telephone interview, Charles Massey, C. H. Guernsey & Co., April, 1980.

²⁸Telephone interview, Lewis Bailey, Blackstone Valley Electric Co., April, 1980.

²⁹Ibid.

³⁰Telephone interviews, Lewis Bailey, Blackstone Valley Electric Co. and Richard James, Wisconsin Public Service Corp., April, 1980.

others.³¹ This was usually handled by writing a letter explaining what was being done and the purpose of the test. Also, the meter readers and installers were given instructions in what to say to customers, who to refer them to for further information, and how to handle complaints.³² The reader is referred to Chapter Three where this is covered more thoroughly.

SUMMARY

Customer response to new TOD or load survey metering is perhaps less planned for than any other aspect of metering conversion. Indeed, what customers think of the new metering itself can be difficult to separate from what they think of the rate structure, experiment, or load study that it subserves.

When customers are billed on the basis of magnetic tape records, they have no way of seeing for themselves the time-differentiated consumption record upon which their total charge depends. With multi-register meters, the customer can in principle at least, read the total consumptions for the separate tariff periods as well as can utility personnel. This difference is no doubt important to matters of customer acceptance and cooperation.

Adverse customer reaction to TOD metering has much to do with ignorance of its characteristics and purpose. Utility personnel have little reason to suppose that customer understanding of meters remotely approximates their own levels of familiarity. Unless this knowledge differential is borne in mind, the reactions of some customers can appear capricious and bizarre.

Customer acceptance of new metering also depends on aesthetic and privacy interests. Large metering configurations can be unsightly, and their anchoring to structures can have bad aesthetic effects on the structures themselves. Indoor installation of meters--inescapable from time to time--can raise very serious issues of privacy and convenience from the customer's point of view.

³¹Telephone interviews, Lewis Bailey, Blackstone Valley Electric Co. and Richard James, Wisconsin Public Service Corp., April, 1980.

³²Ibid.

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CHAPTER :
SIX : SUMMARY
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This chapter presents in summary form a walk-through of the metering experiences. The first step in the process is the selection of meter equipment. This choice was usually based on cost and capability. The experience of the Projects indicates that customer acceptance and understanding may also be criteria.

The utility proposing to undertake load research, TOD studies or implement TOD pricing has the choice of multi-register metering, magnetic tape metering, or an automatic meter reading system. The complexity and resulting operational/maintenance difficulty of these choices increase in the order of their mention. The state of development of automatic meter reading makes it an unlikely means for large scale usage at present. If multi-register metering is chosen, then the further selection of two-register versus three-register meters is to be made on the basis of the chosen rate structure and the likelihood of subsequent changes in rate structure. Two-register meters cost around \$70 per point. The Projects afford only one example of three-register metering, the Arizona Project's two-meter assembly that cost approximately \$150 per point. The choice of magnetic tape meters splits into cartridge recorders versus cassette recorders. While there is little difference in cost between the two kinds of recorders themselves, there is about a four-fold difference in price between cartridges (\$36) and cassettes (\$9).

Battery carryover for either multi-register or magnetic tape meters is very likely indispensable to any large-scale usage, although it is conceivable that extremely low outage frequencies could justify dispensing with it. For magnetic tape recorders, carryover adds about \$70 to the meter cost. Since the Projects that used multi-register meters did not use carryover, it is not possible to document its added cost to multi-register meters on that basis. The list price of one external carryover for the GE

IR-50 and IR-70 two-register meters around 1978 was \$90. But another estimate of the additional cost of carryover for GE multi-register meters was as low as \$10.

The acquisition of meters should be carefully planned beyond just their selection and designation of a vendor. Delays in delivery seemed almost the norm in the Projects; if their example is generalizable, utilities should take steps at the beginning to insure on-schedule delivery, such as inclusion of penalties for late delivery in their meter purchase contracts. Care should be taken that the performance characteristics of the purchased meters are really what the utility needs, i.e., what was actually conceived of as adequate metering and whether what is promised by the vendor actually meets this conception. The Projects did sometimes encounter discrepancies here, as when it was learned after the fact that carryover would have been desirable, or when it was learned that battery carryover does not make loss-of-potential superfluous. There should be well specified quality and performance standards enforced in the acquisition process. Implementations can be badly protracted and hindered by the need to retrieve defective goods and return them to the manufacturer. The close cooperation and good will of the vendor is most important in this connection.

Installation of new metering may require specific technical instruction to relevant personnel; planning for it very likely should include briefing installers as to how to handle questions and other responses from customers and how to present and explain the new metering to them. Space limitations and the requirements of special treatment of customers' property should be foreseen as adequately as possible. There may be conflicting claims upon the time of installers as they are required to perform other duties, especially tape-changing, in addition to meter installation. These potential hindrances to quick, correct implementation should be taken into account and mitigated early.

With the best of planning, the likelihood remains of at least a few unforeseen technical problems of installation (space inadequacy, conditions at service entrance) and problems of

customer acceptance that no amount of preparation could cover.

Magnetic tape meter operations comprise tape-changing, translation of meter tapes into computer-useable form, and editing of translated tapes for various imperfections in the data. The whole process depends at every step upon correct function of fairly complex machinery and correct performance of tasks ranging from modest to high complexity. Errors in tape changing will decline in frequency with time and experience, but they must be expected at a significant instance in the beginning. Nothing but careful instruction and practice can minimize the initial incidence of these problems. Magnetic tape meters are vulnerable to a level of malfunction far worse than present industry norms. Rigorous quality control over new equipment received by the utility, rapid exchange arrangements with the vendor, and high expertise in the meter shop are all indispensable to keeping data losses from meter failure down to tolerable levels. Translator malfunctions are less common than meter malfunctions, but one translator breakdown can be equivalent to a thousand delays in data collection. Errors in editing, or improper editing policies and routines could have even worse effects.

Unless a battery carryover keeps the tape moving and the time-pulse generator working, power outage induces a time error in the consumption record. These errors must be corrected at the translation and edit stages of data handling. Single outages can be compensated for from tape data alone if the magnetic tape meter is capable of indicating loss of potential; multiple outages can be handled only with independent data on their times and durations. A utility that foregoes the use of carryover with magnetic tape meters must be prepared to obtain such data promptly and with confidence in its accuracy. Multi-register metering operations differ qualitatively from single-register operations, mainly in activities required by the presence of time-controlled switching. Without carryover or centrally controlled switching, the time switches must be reset after power outages. Common malfunctions of the timing mechanism

(aside from the motor) ought to be field-corrected by the meter reader; defects in the motor itself are usually problems for the meter shop.

Both multi-register and magnetic tape meters add maintenance checks to regular data collection duties. Tape collectors must at least inspect recording heads at every tape-change, and probably should clean them at every visit to the meter. It is also advisable to have tape collectors test for the transmission of both data and time-pulses by the head after removal of the old tape. When tapes are brought to the central collection point, they should be visually inspected before translation.

Multi-register meter readers should check the time switch for synchrony with standard clocks, and be prepared to inspect the time switch mechanism for simple malfunction if the time is lagging or leading. If the meter has tariff-period indicating lights, these can serve as a rough check of time-switch synchrony.

With either multi-register or magnetic tape metering, the presence of carryover obliges the data collector to check the state of charge and general condition of the battery.

Meter selection, installation operation and maintenance by the utility are all related to customers' reactions. Many of the customer experiences and customer relations of the project had to do with aesthetic reactions to and understanding of the metering equipment. Some customers did not like the appearance of the meter itself, while others were concerned that the installation might affect the appearance of their homes. Some customers did not understand either why the meter was being put up or its operation. For example, there were a number of inquiries about the indicating lights on multi-register meters.

A lack of understanding and dislike of the appearance of the meters may have played a part in hostile or suspicious attitudes on the part of customers. The project teams handled these in different ways. Some were able to anticipate customer reactions and have procedures for dealing with inquiries and complaints. Usually information on the project was supplied. It is not clear, however, that information on the meter itself was

provided for multi-register meters.

Often when a customer was hostile or simply did not like the meter or something about it (e.g., lights) the utility simply disengaged the offending item if possible. Sometimes the situation was resolved by forbearance while in others the customer was removed from the experiment.

While a few customer reactions stand out as openly hostile or suspicious many customers were both curious and cooperative. Some indicated that they appreciated being able to see how much electricity they were using.

As a final comment, it can be said that what may have appeared to be a process of simply installing new meters turned out to be more complex than anticipated. The changes involved required a change in the process, and that required a change in habitual modes of behavior. Perhaps this report will provide a guide to some of the changes, both technical and behavioral, that may be expected when TOD metering is installed.

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED
DATE 08-11-01 BY 60322 UCBAW

APPENDIX 1

LIST OF ELECTRIC UTILITY DEMONSTRATION PROJECTS
AND LIST OF PERSONS INTERVIEWED

TABLE 1A

ELECTRIC UTILITY DEMONSTRATION PROJECT PARTICIPANTS

Project Location	Participants	Performance Period	Key Project Personnel
Arizona	Solar Research Commission (s) -Arizona Public Service Co.(u)	6/75-12/76 ^a	James F. Warnock (SRC) Doug S. Windes (DOE)
Arkansas	Public Service Commission (s) Arkansas Power & Light Co.(u)	6/75-9/77	James F. Herden (APSC) Ralph Teed (AP&L) Doug S. Windes (DOE)
California	Energy Resources Conservation & Development Comm. (s) Public Utilities Comm. (s) Pacific Gas & Electric Co. (u) San Diego Gas & Electric Co. (u) Southern Calif. Edison Co.(u) Sacramento Municipal Utility District (u)	7/76-P	Richard M. Hairston (ERCDC) Roger Levy (ERCDC) John Flory (ERCDC) Jackalyne Pfannenstiel (Smith) formerly of Connecticut PUCA Doug S. Windes
Connecticut	Public Utilities Control Auth.(s) Connecticut Light & Power Co. (u) (continued)	6/75-3/77	Jackalyne Pfannenstiel (Smith) (Conn. PUCA)

TABLE 1A (continued)

Project Location	Participants	Performance Period	Key Project Personnel
Edmond, Oklahoma	City of Edmond Edmond Municipal Electric Co. (u)	12/76-6/78	Paul Buntz (EO) Doug S. Windes (DOE)
Los Angeles, California	Department of Water & Power	6/75-9/79	Dennis B. Whitney (LADWP) Doug S. Windes (DOE)
Michigan	Public Service Comm. (s) Detroit Edison (u)	8/75-12/77	Robert Benko (PSC) Jane Christophersen (DOE)
New Jersey	State Energy Office (s) Jersey Central Power & Light Co. (u)	6/75-5/80	Charles Richman (SEO) Paul Johnson (DOE)
New York	Public Service Comm. (s) Consolidated Edison (u)	1/76-6/77	Joseph Rizzuto (PSC) Doug S. Windes (DOE)

(continued)

TABLE 1A (continued)

Project Location	Participants	Performance Period	Key Project Personnel
North Carolina	Utilities Comm. (s) Carolina Power & Light (u) Blue Ridge Electric Membership Corp. (u)	7/76-8/79	Antoinette Wike (UC) Jane Christophersen(DOE)
Ohio	Public Utilities Comm. (s) Dayton Power & Light Co. (u) Toledo Edison Co. (u) Buckeye Power Co. (u)	6/75-3/78	Robert Wayland (PUC) Jane Christophersen(DOE) Joseph Wathen (PUC)
Puerto Rico	Commonwealth Water Resources Authority (u)	7/76-7/80	Alberto Bruno-Vega (C) Paul Johnson (DOE)
Rhode Island	Public Utilities Comm. (s) Blackstone Valley Electric Co. (u)	9/76-10/78	Thomas Chmura (PUC) Lewis Bailey (BVEC) Christina VanSickle(DOE)

(continued)

TABLE 1A (continued)

Project Location	Participants	Performance Period	Key Project Personnel
Vermont	Public Service Board (s) Green Mountain Power Co. (u)	11/74-1/77	Wayne Foster (PSB) Charles Elliott (GMPC) Larry Kaseman (DOE) Doug S. Windes (DOE)
Washington	State Energy Office (s) Seattle City Light (u) Clark County PUD Puget Sound Power & Light Co. (u)	9/76-10/78	Jacob Fey (SEO) Nancy Tate (DOE)
Wisconsin	Public Service Comm. (s) Wisconsin Public Service Corp. (u)	9/75-11/80	James Simpson (PSC) Jane Christophersen (DOE) Richard E. James (WPSC)

Source: Compiled from Electric Utility Demonstration Project Reports and documents and interviews, 1975-1980

^aProject was completed as far as DOE involvement was concerned. The experimental TOU rates have continued to date.

^sParticipating state or city agency.

^uParticipating utility.

TABLE 2A
LIST OF PERSONS INTERVIEWED

Name	Address
<u>Department of Energy Personnel</u>	
M. Larry Kaseman	U. S. Department of Energy Economic Regulatory Administration Division of Regulatory Assistance Washington, D. C.
Steven Mintz	"
Douglas Windes	"
Jane Christophersen	"
Christina VanSickle	"
Paul Johnson	"
<u>Project Participants and Consultants</u>	
Lewis Bailey	Blackstone Valley Electric Company Providence, Rhode Island
William Bowman	North East Utilities Hartford, Connecticut
David Bryant	Arkansas Power and Light Company Little Rock, Arkansas
Don Burbank	North East Utilities Hartford, Connecticut
Porter Cleveland	Green Mountain Power Corporation Burlington, Vermont
Neil Dikeman	University of Oklahoma Norman, Oklahoma
Henry Duckworth	Dayton Power and Light Company Dayton, Ohio
John Flory	California Energy Commission Sacramento, California

(continued)

TABLE 2A (continued)

Name	Address
David Goeckler	Kansas City Power and Light Company Kansas City, Missouri
Paul Hart	Arizona Public Service Company Phoenix, Arizona
Upton Henderson	Central State University Edmond, Oklahoma
Richard E. James	Wisconsin Public Service Corporation Green Bay, Wisconsin
Roger Levy	California Energy Commission Sacramento, California
Charles W. Massey	C. H. Guernsey & Company Consulting Engineers and Architects Oklahoma City, Oklahoma
Jackalyne Pfannenstiel (Smith)	California Public Utilities Commission Sacramento, California
Earl Taylor	North East Utilities Hartford, Connecticut
Joseph Wathen	Ohio Public Utilities Commission Columbus, Ohio
Dennis B. Whitney	Los Angeles Department of Water and Power Los Angeles, California
Billy Yarborough	Carolina Power and Light Company Raleigh, North Carolina
John Zulauf	Dayton Power and Light Company Dayton, Ohio

Source: The Author was directed to these persons by correspondence and telephone communications from DOE, Project documents, and recommendations of some of the interviewees themselves.

APPENDIX 2

GLOSSARY

GLOSSARY

This glossary contains definitions of key concepts in Time-of-Use metering as well as definitions of meters and metering related equipment.

AUTOMATIC METER READING - A system in which a transmitter at each metering point sends accumulated data on consumption or demand through a communication network to a central processing station where these data are converted into the billing basis.

CALENDAR CAPABILITY - Control of register-shift (either in kwh or kw measurement) over longer-than-daily time periods such as day-to-day shifting of peak, mid-peak, and off-peak periods, exemption of weekends from TOD billing, adjustment for seasonal peak shifts, and adjustment for daylight savings time and leap years.

CARRYOVER - A reserve power source for TOD meters, independent of the 60 Hz line, to continue operation of time-keeping functions during power outages. They operate the time switch in multi-register meters, and the time-pulse generator and tape drive in magnetic tape meters. Carryovers are usually an integral part of the time switch connected to multi-register meters lacking internal controls. They can be an external attachment to multi-register meters with their own time controls or an integral part of programmable meters (q.v.).

DEMAND INDICATING METER - A device that records the greatest power (kw) drawn at the metered point during the period between meter-readings. Usually an added feature to the standard watt-hour meter. In its standard form does not show when peak demand occurred. An external clock control can be used to activate the indicating demand meter at certain times of day thus allowing determination of maximum power drawn during, e.g., the system peak hours.

DEMAND RECORDING METER - A device that records the energy consumed during consecutive brief (usually 15-minute) intervals throughout the billing period. The brevity of the integrating interval allows these totals to be interpreted as power measures.

DEMAND-SWITCHED MULTI-REGISTER WATTHOUR METER - An energy consumption meter with one register continuously engaged and one or more additional registers engaged or disengaged as demand at the metering point exceeds or falls below pre-established levels. This type of meter suits rate structures that charge differentially for kwh consumed at different customer - not system - demand levels. It is not applicable to TOU rate structures. Also called a Differential Register Meter.

ENCODER - A component of an Automatic Meter Reading system that translates register contents (usually accumulated dis-rotations) into signals transmissible over the communications medium.

ENERGY PLUS DEMAND METER - A single - or multiple-register watt-hour meter for record of energy consumption confined in a single unit with one or more kw demand indicating devices for measuring the peak power drawn, either over the entire billing period or within different rate periods. Also called a Three-Part Rate Meter.

MAGNETIC TAPE DEMAND RECORDER - A magnetic tape device that records a pulse initiated by each disc revolution of a standard watthour meter, along with time-reference pulses generated by a local clock.

NON-VOLATILE MEMORY - An electronic record of consumption and/or peak demand in programmable solid state meters that is not vulnerable to power outage. This term applies as well to the programmed logic functions of these meters which are maintained during power outage. Volatile memories are dependent upon power input to the meter and hence are destroyed by power outage.

POWER LINE CARRIER (PLC) SYSTEM - Communication between a central control/data-reception station and metering/end-use points by way of relatively high frequency (5-300 kHz) signals injected into the transmission and distribution grid.

PROGRAMMABLE METER - A multi-register meter controlled by electronic microprocessor circuitry, usually providing some degree of calendar capability (q.v.) in addition to TOD rate-period differentiation. The time-differentiated tariff structure is programmed into the controlling electronics.

REMOTE TIMING CONTROL - Activation of register shifts in multi-register meters from a central control point by way of any of a variety of communications media (telephone line, power line, radios, CATV, dedicated pilot wire).

SOLID-STATE ELECTRONIC DATA RECEIVER - A six-register programmable signal-processor wired to a standard watthour meter. Pulses initiated by revolutions of the meter disc are sent to one kwh consumption register and one kw demand register for each of three tariff periods during the day. The unit thus processes the same raw data as enters the Magnetic Tape Demand Recorder. Rather than recording the pulses against a time reference, the Data Receiver converts the pulse total and the pulse rate on site into energy consumption and demand data.

THREE-REGISTER WATTHOUR METER - A watthour meter with one set of dials that accumulates total energy consumed, a second set that is engaged only during the 'shoulder' portions of the system load curve, and a third set that is engaged only during the system peak period. The 'off peak' consumption is determined by

the difference: Total kwh - ('shoulder' kwh + 'peak' kwh).
Also called a Three-Rate Watthour Meter.

TIME SWITCH - A clock-activated device either built into a multi-register meter or externally connected to it; which controls the registers in operation at different tariff periods.

TWO-REGISTER WATTHOUR METER - A watthour meter with one set of dials that is engaged at all times, accumulating total energy consumed to the present, and another set of dials engaged only during the premium tariff period ('on-peak' hours, typically). The 'off-peak' consumption is determined by the difference: Total kwh - 'on peak' kwh. Also called a Two-Rate Watthour Meter.

WATTHOUR METER - A single-register meter that accumulates a record of the total energy (kwh) consumed since installation or reset. Cannot be used with any TOU rate structure in which the tariff changes more frequently than once per billing period. This is the most commonly used type of meter in the residential sector.

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