NISTIR 5564

The Technical Impact of the NIST Calibration Service for Electrical Power and Energy

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Arati Prabhakar, Director

FOREWORD

The National Institute of Technology (NIST) establishes and maintains the values of the primary electrical units of measurement in the United States. The Electrical Systems Group, part of the Electronics and Electrical Engineering Laboratory, allocates some of its resources toward maintaining the quality of its services for calibration of watthour meters.

To assess the impact of this resource allocation and focus the activity on the needs of the industry, a survey was developed and conducted to obtain technical and economic information from the beneficiaries of the service. The survey was addressed to individuals identified as technical points of contact in the industry, requesting from them both technical and economic information. As it turned out, the responses provided valuable insight on the structure of the industry and its relationship to the NIST services. However, the responses to economic questions did not offer a clear picture because many respondents did not have the information available. In some cases, the replies provided conflicting data within one questionnaire, or were difficult to place on a consistent basis for compilation of statistics.

Consequently, the scope of this study, which aimed at assessing both the technical and economic impact of the calibration services, was changed to focus on a primarily qualitative description of the technical impact. A separate study was then conducted, based on a different approach for collecting more precise economic information, and is reported in a companion report.[1]

This report provides a description of the relationship between NIST and the stakeholders in power and energy metrology. Emphasis is given to the electric utility industry, where the energy measurement is directly tied to the revenue. The instrument manufacturers of course are involved in producing the measuring instruments (reference standards as well as revenue meters), while the public utility commissions are involved in the regulatory aspects of transactions between producers and consumers of electric energy.

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1 A.N. Link, *"An Evaluation of the Economic Impacts Associated with the NIST Power and Energy Calibration Services,"* NISTIR 5565, 1995.

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SUMMARY

A survey was conducted to assess the economic impact of the NIST Power and Energy Calibration service. Information was sought from electric utilities, meter and instrument manufacturers, testing laboratories, and public utility commissions on the structure of their operations and the economic aspects related to traceability to National Standards maintained by NIST.

The information returned by the respondents was not sufficiently comprehensive and consistent to allow broad generalization leading to a reliable assessment of the economic impact of the NIST services. However, the technical impact of these services was sufficiently documented to present this report describing the infrastructure and the relationships among the stakeholders.

1. THE ROLE AND RESPONSIBILITIES OF NIST TO THE ELECTRIC POWER INDUSTRY

1.1 The motivation for an impact study

NIST is mandated by law

The National Institute of Standards and Technology (NIST) has by law the mandate to provide for industry access to a system of uniform and consistent measurements. Important measurements within the electric utilities include energy measurements for revenue billing to customers, other measurements for the control of the utility systems, and measurements for determination equipment efficiency. The principal instrument used to measure the electric energy flowing throughout the utility systems and ultimately to the consumer is the **watthour meter**. Thus, the watthour meter is indeed the "cash-register" of every electric utility.

Economic data are difficult to obtain from technical people

The initial purpose of this impact study was to assess qualitatively and quantitatively the technical and economic impacts of power and energy metrology and the NIST calibration services for electrical power and energy on the U.S. electrical power industry and supporting measurement community. As described later in this report, the economic data obtained from respondents did not provide enough basis for firm conclusions, so that the final scope if this report is limited to technical impacts. For a historical and anecdotal perspective, some discussions are included on attempts at collecting economic data and the limited results obtained in that area.

A separate economic study was conducted

A separate study of economic benefits was conducted on the impact of these services, which is documented in a companion report (Link, op. cit.). The results of the present study on the technical impact, as well as the results of the companion economic impact study, will be used to guide improved NIST calibration services and research programs to respond effectively to present and future industry and laboratory needs.

1.2 Absolute, basic and derived units

At the beginning, just small watt-seconds

Beginning with the absolute units of mass, length, and time as maintained by NIST, the basic electrical quantities of voltage, current, and impedance are derived. These, in turn, support the NIST derivation of the National Standards for electric power and energy. The derived unit of power is the **watt**; the unit of energy used for billing customers is the **watthour** (generally stated in kilowatt-hours). In scientific and Système International (SI) units, the unit of electric energy is the **joule**. To convert between units, the relationship of *1 joule = 1 watt·second*, or *1 watt·hour = 3600 joules* may be used

Total of U.S. electric energy consumed is big 3 trillion kilowatt-hours

As with any industry, the interchange of goods and services requires that these quantities be measured. For the electric power industry in the United States, principally the electric utilities, the commodity that is produced and delivered is nearly 3 trillion (3×10^{12}) kilowatt-hours of electric energy. This service includes the availability of the more than 1 million km (600,000 miles) of transmission and distribution lines (22 kV and higher) that provide this energy to every corner of the United States. All this electric energy is measured many times -- from its sources of generation, through the transmission and distribution systems, and finally when delivered to the ultimate end-user.

There are five client groups for NIST calibrations

To understand and appreciate the role of NIST and the utilization of its calibration services by the U.S. electric industry and related businesses, it is useful to examine the infrastructures of the individual sectors of the electric industry that make use of the NIST calibration service for power and energy measurements. The sectors of the electric industry that make the principal use of the NIST calibration services are:

- Electric utilities, consisting of investor-owned companies, municipal systems, and government-owned and operated systems;
- Electric revenue-meter manufacturers;
- Electronic instrument manufacturers;
- Commercial testing and metrology laboratories providing calibration services;
- State Public Utility Commissions regulating electric utilities.

1.3 The consumers of electric energy

There are four groups of end-users

All of the industry sectors listed above ultimately serve the needs of the consumers of electric energy, generally called end-users in the electric utility industry. These can be classified into four groups. The groups are shown in Table 1 below under three headings of respective *numbers of end-users, energy sales,* and *revenue dollars*. It is interesting to note that in terms of energy sales and revenue, the proportions are approximately equal for each group of residential, commercial, and industrial end-users.

TABLE 1
Classification of electric energy end-users

End-user Groups	End-users		Energy sales		Revenue	
	Millions	Percent	kWh billions	Percent	$ billions	Percent
Residential	97	87	924	34	72	40
Commercial	12	11	751	28	55	31
Industrial	1	0.9	946	35	45	25
Other	1	0.9	92	3	6	3
Total	111	100	2713	100	178	100

Note: The totals may not equal the sum of the components because of independent rounding.

Source: Energy Information Administration, *Electric Sales and Revenue (DOE/EIA 0540(90)).*

Residential end-users are by far the largest in number (87%) and pay the largest share of revenue (40%). Commercial end-users are second in numbers and revenue, but third in energy sales. The largest end-user of electric energy is industry (35%), yet they account for a modest 25% of the revenue. The group of "other" representing only 3 percent of the sales and revenue, includes public street and highway lighting, other sales to public authorities, sales to railroads, etc.

There are more than 100 million meters in service

To measure and bill this energy, there are over 100 million watthour meters in service in the United States. Each of these meters has been adjusted during its manufacture, checked again when purchased by a utility, and often tested again at some point in its lifetime to assure that it is measuring within an established limit of accuracy. A chain of measurements is used to refer each adjustment, test, and calibration against a reliable standard.

1.4 The suppliers of electric energy

There are 3200 electric utilities in the U.S.

There are approximately 3200 utilities in the United States, most of which are small, publicly owned municipal systems and rural electric cooperatives. Ownership of the U.S. electric utilities is made up of the major categories as shown in Figure 1.

Of the total supply of U.S. electric energy, 76% is produced by the 265 investor-owned utilities. About half that amount (38% of the total U.S. energy) is provided by only about 25 of the largest investor-owned utilities. Figure 2 shows energy sales (in billions of kilowatt-hours) and Figure 3 shows the total revenue (in billions of dollars) for four ownership classes. The "size" of an electric utility may be described by a variety of different measures, such as those listed below:

Sales of energy (kWh) to end-users
Generation capacity
Revenue
Number of customers
Service area served
Number of miles of transmission and distribution lines

Public-owned utilities are the largest group

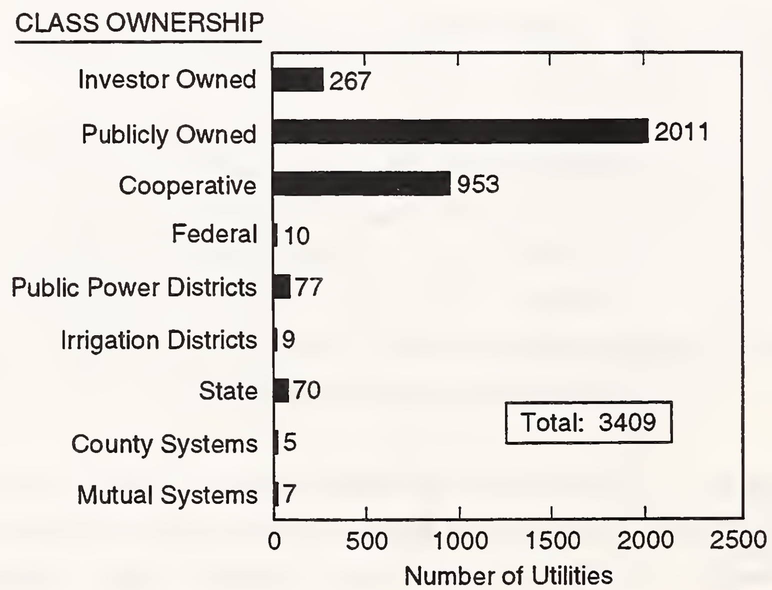

Figure 1 - Number of U.S. electric utilities by class of ownership

For the purposes of this report, "size" is defined in terms of energy sales, unless otherwise specified. Another useful indicator might be the number of meters purchased, calibrated, adjusted, or tested as a measure of utility activity, although it is somewhat unique to this study and the number of meters processed is generally not a common measure of utility size.

Investor-owned utilities produce 75% of the U.S. electrical energy

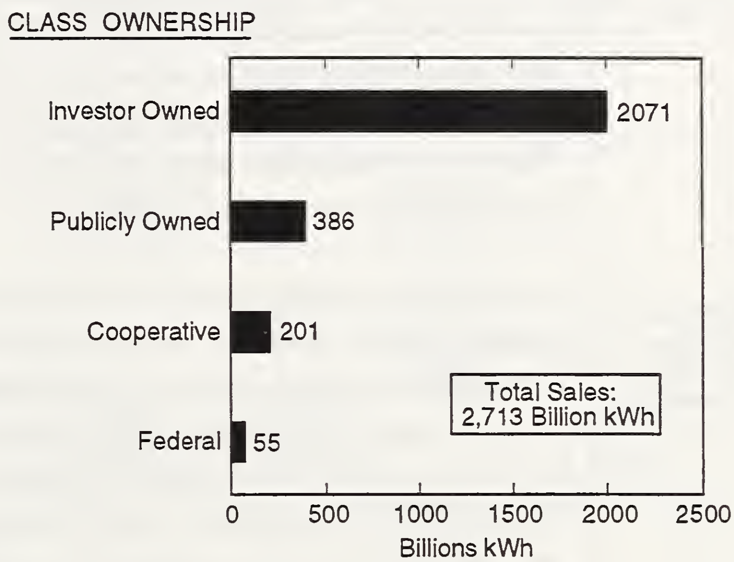

Figure 2 - Electric energy sales to end-users by class of utility ownership

Investor-owned utilities collect 80% of the revenue

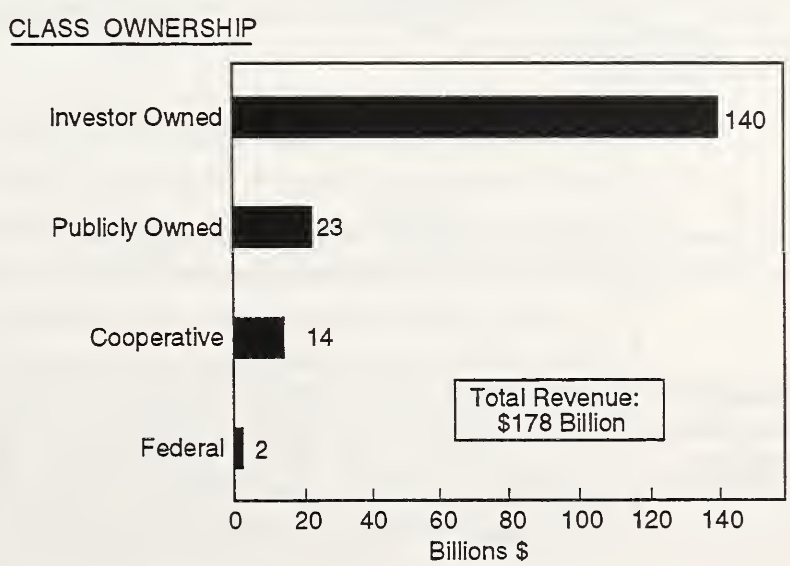

Figure 3 - Revenue of electric energy sales by class of utility ownership

Additional end-user meters are necessary

"Submetering" is another emerging area of metering concern in many locations. Owners of multiple-tenant housing, such as apartments and condominiums, and other commercial concerns such as marinas, recreational vehicles and mobile-home parks, convalescent homes, and shopping centers, can install their own private meters for the purpose of selling electricity to the "occupants." State regulations may or may not apply, depending on the state. In instances where it is permitted and regulated, some form of measurement traceability is required. This requirement has brought in a new measurement need to ensure trade equity, that is, protection that the consumer is not being overcharged for the energy that is being consumed. Furthermore, individual metering is now required on new constructions as part of energy conservation efforts.

Additional meters within the utility system

Large utilities usually generate their own electricity for sale. Many small utilities, such as municipal systems and cooperatives, often purchase electricity from some larger utility for resale. In these instances, the watthour meter is involved in both the purchase and resale of the energy. Additional utility power and energy measurements are in the operation of their generation, transmission, and distribution systems. These are often very large and expensive installations, having collectively, nationwide total assets reaching $500 billion ($\$5\times10^{9}$) , of which two thirds are attributed to net utility plant assets (hardware and facilities). Their efficient management and safe operation (especially for nuclear plants) is a must and relies on, among other things, power and energy measurements throughout the entire system.

Calibrations are performed by NIST or by others

In addition to the revenue meters that mark the interface between the utility and the end-user, there are many meters used throughout the utility systems. Figure 4 indicates the many possible locations in the upper part of the figure, each possible location being designated by a letter "M" to indicate "meter". A typical meter shop is shown at the center of the figure, which is responsible for the maintenance and support of metering activities of the utility. The typical calibration support of such metering is shown in the lower portion of the figure. Standards for calibration are provided, as indicated, typically by two sources, either directly by NIST, or by an independent testing or calibration laboratory.

6

Many meters and many kilometers (miles) to go

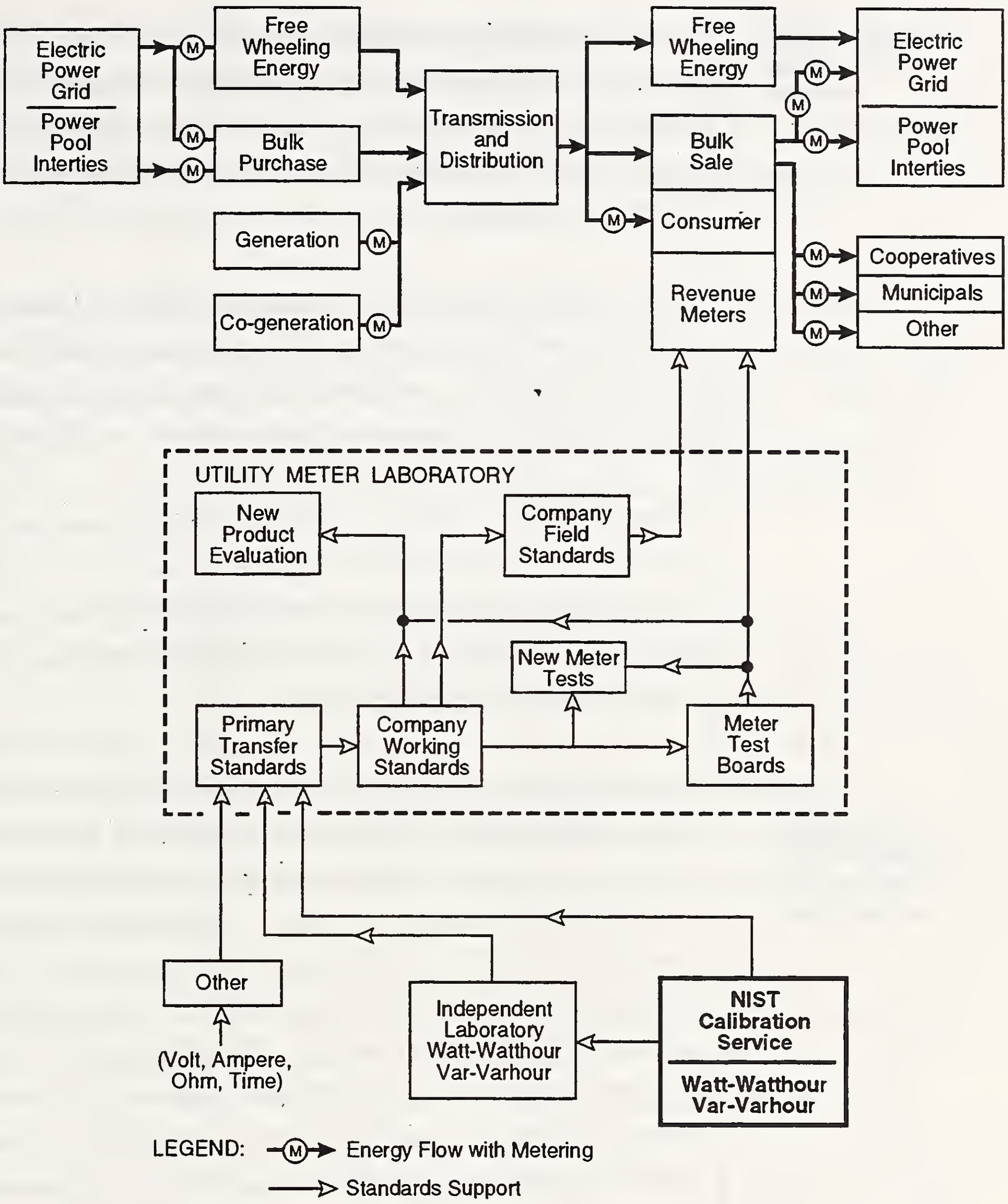

Figure 4
Revenue metering and system metering supported by NIST Energy Calibration Services in a typical utility

In the parlance of the utility meter shop, "testing" is a measuring process wherein the registration of the meter is determined. No adjustments are made to the meter. "Calibration," on the other hand, is a measurement process wherein the adjustments are made on the meter to set the meters' registration. "Repair" of meters requires new calibration and adjustment.

Sample testing is a comon practice

At the utility, the testing of *new meters* is very often done on a sampling basis. A predetermined portion of the total number of meters purchased in a lot are selected based on a statistical sampling plan. The specific portion varies from one utility to another, depending on the statistical criteria that have been chosen.

Most utilities also perform sample testing of meters in service. These meters are removed from service and tested "as found" to determine, on a statistical basis, the general condition of the meters in the utility service area. Records are kept to help guide the future operations of the metering function.

Many of meters that are tested are meters that have been removed from service to be upgraded or repaired as necesary. Upgrading, for example, may be the changing of the mechanical register to an electronic time-of-day register. Any time a meter is modified, repaired, or upgraded, the meter must be tested and calibrated.

The utility's meter shop is responsible for accuracy

In order to ensure that accurate calibration measurements are being made, most utilities (especially the larger utilities) have meter shops that maintain and use standards. Utilities are very conscientious in maintaining good and accurate measurement practices. Errors in the measurement of energy to the consumer represents an inequity. That error may be in the favor of the consumer, in which case the utility is losing revenue. Or the error may favor of the utility, in which instance the utility is overcharging the consumer. In the latter case, most State Public Commissions generally state that the metering error be maintained at less than 2%. Most utilities will maintain metering uncertainties as low as 0.5% for residential and commercial accounts, and 0.1 to 0.25% for large industrial accounts. Even small errors of a few tenths of one percent can collectively represent huge sums when considering the "electric bill" for the United States. However, as pointed out by Link (op. cit.), while the inequity is objectionable to the impacted party, it not relevant when considering the national economy because of cancellation.

Direct traceability

About 4 million meters are tested and calibrated by the utilities in the United States annually. The **standards** used by the utilities, usually an **electronic watthour meter**, are traceable to the NIST calibration service for power and energy. When directly traceable, the utility ties **directly** to NIST with a standard without any other party between.

Indirect traceability

Two common examples of **indirect** traceability are when a utility relies on
1) the calibration services of an instrument manufacturer, or
2) a metrology or test laboratory specializing in calibration. In either case, the parties that provide calibration services for manufacturers or laboratories maintain traceability to NIST.

As stated earlier, while NIST has a legal mandate to maintain ***basic standards,*** such as the volt and the ampere, standards for power and energy are ***derived quantities*** and are not considered a basic standard. The NIST calibration service for electric power and energy is offered to the electric industry on economic efficiency grounds, rather than as a mandated and exclusive service.

Derivation by others is possible ...

Therefore, it is possible for a company or utility to derive the watt or watthour from standard units of voltage, current, impedance, and time and not rely on the NIST power and energy calibration service. This derivation has been commonly done in past years. Even now, it is performed occasionally by a few of the companies or utilities where the highest accuracy is not required. However, individual derivation requires expensive replication of this process at many locations across the country at a much greater overall cost.

... but not very cost-effective

The measurement accuracies now required at the utility level are such that most utilities simply do not have the equipment, knowledge, or economic resources to perform such derivations of the watt and watthour. Some meter and instrument manufacturers do derive their own standards of power and energy from the units of voltage, current, impedance, and time for their special needs. In general, however, it would not be cost effective for these user industries to invest in the facilities and trained staff to advance and assure the needed increases in measurement accuracy and precision.

2. SUPPORTERS OF THE UTILITIES AND THE ELECTRIC POWER INDUSTRY

There are many supporting sectors of the U.S. economy and business world that provide the necessary goods and services to maintain the electric production in the United States as a successful and vital service. The sectors that are of principal interest to this study are those that use and rely on electric power and energy measurements as a part of their operations. These can be divided into the categories shown below. How the measurements are made and why they are economically important to each of these categories will be examined.

There are six supporters for the electric power industry

- Electrical equipment and hardware manufacturers and suppliers
- Meter manufacturers
- Instrument manufacturers
- Testing and metrology laboratories
- Public Utility Commissions/Public Service Commissions
- National Institute of Standards and Technology

2.1 Electrical equipment and hardware manufacturers and suppliers

Measuring energy at the source is important

The generation and distribution of electric energy requires the use of expensive hardware such as generators, transformers, switchgear, circuit breakers, and other important components within their systems. The measurement of electric power and energy in many of the system components is important. This is especially true for generators and transformers where the assessment of operating efficiency is of paramount interest. The lifetime costs of losses due to inefficiencies in generators, transformers, and reactors often exceed by several times their original cost.

Efficiency measurements are demanding

The accurate measurement of losses in transformers is among the most difficult power measurements that the industry is called upon to perform. Likewise, this requirement creates the most demanding challenge NIST for the highest accuracy calibrations that are state-of-the-art. For example, if a 1% loss is to be determined with an uncertainty of ±1%, calibration requirements of ±0.01% or less are required. (Fundamentally, it can be thought of as a ±1% uncertainty of a 1% loss, or $\pm 10^{-2} \times 10^{-2} = \pm 10^{-4}$, or ±0.01% measurement uncertainty.)

Generators are designed and sold with specifications of being capable of producing specified amounts of power for periods of time without overheating or mechanically failing. It is therefore necessary for the manufacturers of such heavy equipment to measure the generator outputs to ensure that the specifications are being met. Additionally, the utility that is purchasing the generator also may test its power delivering capability. These types of field measurements are very difficult to perform, yet they are very important to the industry. The same general measurements are made also on transformers and reactors to guarantee performance.

2.2 Meter Manufacturers

There are four manufacturers of revenue meters

In the United States, there are four major companies that manufacture rotating (inductive disc type) watthour meters of the electro-mechanical design. These types of meters are used at residential, commercial and industrial sites. Within the past 10 or so years, "all-electronic" meters have been available from other manufacturers, and recently, also from the same four manufacturers that produce the inductive type meters.

The meter manufacturers play a very important role in the support of the electric industry. Foremost, the watthour meter, whether it is inductive or electronic, is essentially the “cash register” for the utility businesses. All electric energy sold (and sometimes bought, then resold) is measured by these watthour meters. Without the watthour meters, the utility businesses simply could not exist.

These meters are also used throughout the utility systems for measurement and control. A variety of other meter types and instruments, such as those used for measuring current, voltage, temperature, pressure, etc., are also used, but they are not considered in this report. It is the watthour meter that is of critical importance to the utility.

Each year, over 4 million meters are manufactured in the U.S.

There are more than 4 million watthour meters manufactured annually in the United States. During manufacturing, these meters are adjusted and calibrated to be within specified limits of performance. Generally, the percentage registration of the meters is adjusted to have errors less than ±0.1% at specific test conditions. Such precise adjustments requires a careful program of calibration where their standards may be calibrated to uncertainties of ±0.01% or better.

All meter manufacturers submit their standards to NIST for calibration. These standards in turn are used to maintain the working standards of the manufacturer, and those working standards are used to maintain the production facilities. Daily or weekly checks are typically made to ensure that changes have not occurred in their manufacturing process.

Acceptance of sample testing is based on traceability

When utilities receive a large shipment of meters, it is common practice to check their performance. This may be done on a sample basis. Acceptance of the meters by the utilities is based on the results of such checks. It is essential that the utilities have a solid program for maintaining their standards that are used to support their testing programs. Larger utilities typically have their standards calibrated by NIST or by other calibration laboratories whose standards are traceable to national standards. Smaller utilities may submit their standards to NIST, but more likely utilize some third party source that is in turn traceable to NIST.

2.3 Instrument Manufacturers

Meters are not just for revenue

Manufacturers of precision power and energy measuring instruments play an important supporting role for the electric power industry. The principal products of interest to this study are those instruments that measure power and energy. They are not used for revenue metering in any sense. These instruments differ from the revenue meters in that they are intended to be used under field or laboratory conditions and are not used in permanent installations. In general, they are multi-range and have lower uncertainties (i.e., better accuracy) than revenue meters. Furthermore, they usually operate over a wide range of frequencies.

Available instruments have ranges of claimed uncertainties from ±0.005% to several percent. They may be single phase or polyphase instruments and are useful to the utilities, meter manufacturers, commercial testing and calibration laboratories, and to some public utility commissions. Such devices are often used by manufacturers in their research and development activities supporting their product lines. Utilities may use such instruments in the maintenance of their testing and calibration programs. Commercial testing and calibration laboratories may use such instruments as standards and principal tools to perform requested tests. Some Public Utility Commissions may use such instruments in support of their operations if they perform tests or calibrations.

2.4 Commercial Testing and Calibration Laboratories

Private sector firms provide calibration services

A number of small businesses perform testing and calibration of meters and instruments. The important service they provide is a traceability link between a utility and national standards. The calibration uncertainties achieved by these laboratories are likely to be greater than those achieved by NIST, but are less expensive to attain. In instances where somewhat less accuracy is acceptable to a utility, commercial testing and calibration laboratories provide a service that is an alternative to NIST calibrations.

The economic contributions from the commercial testing and metrology laboratories to the overall power- and energy-related calibrations in the United States are small in comparison to the role of utilities and meter manufacturers. Yet, these laboratories play an important role in providing a "link" to national standards for many small utilities and other users of electric energy. Because of this link, it is important to recognize their contribution. Equally important is an assessment of their views toward the importance of NIST calibration services and programs that directly support their operations.

Compared to the more than 3000 electric utilities, the population of electrical testing laboratories that provide traceable measurements for power and energy is relatively small. The National Electrical Testing Association (NETA) has 34 member companies, nine of which provide power and energy calibration services.

2.5 Public Utility Commissions

Public Utility Commissions act as referees

Public Utility Commissions (PUC) regulate the electric utilities. Some PUC regulations dictate measurement accuracies and traceability to national standards, but some do not. Among the regulations are those that state the maximum limits of error for revenue meters. In general, the limit of error is 2%. By dictating the maximum limits of error, they in effect mandate a system of calibration hierarchy. In today's marketplace, an error as large as 2% is unacceptably large in terms of revenue metering. This is especially true for the large business and industrial accounts, or at intertie points between utilities.

It is prudent business practice by the utilities to maintain measurement uncertainties in the order of 0.25% or better, strictly based on equity of trade motivation. The referenced Link report documents the psychological leverage of recognized traceability and low uncertainty which result in transaction costs savings by avoiding costly disputes.

Public Utility Commissions maintain traceability

About one-third of the PUCs in the United States maintain standards of their own where they monitor tests between utilities and utility customers. In fewer cases, the PUC may provide a calibration service of standards for the utilities within their jurisdiction. In a few states, type approval must be obtained by the utility from the PUC before meters can be used in those states. In each of these cases, the PUCs maintain traceability to national standards, either by using the NIST services directly, or by using some commercially available and traceable source. NIST has direct dealings with six PUCs regarding electric power and energy.

2.6 National Institute of Standards and Technology

NIST is the ultimate referee for standards

The role of the National Institute of Standards and Technology (formerly the National Bureau of Standards) is simple but essential. As stated earlier, NIST provides a uniform set of standards based on fundamental units through its calibration services. NIST provides this support to each sector of the U.S. power industry. By providing the same uniform calibration service to each, the common measurement basis is formed whereby any one party can interchange measured quantities with any other party. By providing this common basis, disputes and differences between buyers and sellers are greatly reduced.

3. SURVEY METHODOLOGY

3.1 Surveyed stakeholders

Four groups of calibration clients were surveyed

The segments of the electric power industry that make the greatest use of the NIST calibration services and that can be expected to receive the most significant impact are the following:

- Electric utilities: investor-owned companies, municipal systems, rural electric cooperatives, and government-owned and operated systems;
- Electric revenue meter and instrument manufacturers;
- Commercial testing and metrology laboratories;
- State Public Utility Commissions.

Four types of questions were asked

In the initial scope of the study, four categories of economic questions to be asked from the four groups of participants had been identified, as shown in Table 2. The more detailed questions of the survey questionnaire were derived from these four categories of questions. To provide some perspective on the scope of the project, these questionnaire forms are reproduced in the Appendix.

The four categories of questions and the four participant groups were expected to produce a valid sample, from which projections to the national scale could be applied. However, this expectation was not realized as the economic information responses were insufficient, and only a few narratives were received. Section 4 includes examples of some of these anecdotes.

The three categories of quantitative questions asked each participant were designed to determine the following factors:

- Size and scope of the participants operation, in terms appropriate for each;
- Expenses of maintaining meter shop and calibration laboratories as well as performing tests;
- An estimate of their costs if NIST were to discontinue its power and energy calibration services;

The fourth category was an invitation to provide a quantitative or qualitative narrative on the significance (impact) of the NIST program.

Table 2 - Categories of questions and participant groups

Question Category	Electric Utility	Meter and Instrument Manufacturers	Testing and Metrology Laboratories	Public Utility Commissions
Size and Scope	Number of meters purchased Number of meters tested Sales revenue $$ Energy sold, kWh	Number of meters or instruments manufactured Sales revenue $$	Number of meters or instruments tested or calibrated Services revenue $$	Number of meters calibrated Number of tests performed or witnessed
Operating Expenses	Cost of maintaining test and calibration facilities Cost of calibrating standards	Cost of maintaining test and calibration facilities Cost of calibrating standards	Cost of maintaining test and calibration facilities Cost of calibrating standards	Cost of maintaining test and calibration facilities Cost of calibrating standards
"What-If" Cost if NIST discontinues service	Initial cost of establishing new capability Annual cost of maintaining new capability	Initial cost of establishing new capability Annual cost of maintaining new capability	Initial cost of establishing new capability Annual cost of maintaining new capability	Initial cost of establishing new capability Annual cost of maintaining new capability
Narratives and Calibration Payoffs	Savings because of calibration or NIST traceability	Savings because of calibration or NIST traceability	Savings because of calibration or NIST traceability	Savings because of calibration or NIST traceability

3.2 Size and Scope

Size is all relative

In terms of "size" of participant operations, the measure is different for each participant group.

The size of an electric utility could be assessed by three parameters:

1) the annual electric energy sales (kWh), revenue ($), and number of ultimate consumers,
2) the number of meters purchased annually,
3) the number of meters tested, repaired, and calibrated annually.

The size of revenue meter and instrument manufacturers could be assessed by two measures:

1) the number of meters sold annually,
2) the income from meter sales ($).

The size of metrology and testing laboratories could be assessed by:

1) the number of meters tested, repaired, and calibrated, and
2) the income from such testing and calibration.

The size of Public Utility Commissions could be assessed by:

1) the amount of electric energy consumption and number of ultimate consumers for each of their respective states
2) the number of tests performed or witnessed,

3.3 Operating and Maintenance Expenses

Seeking other economic factors

A set of questions was asked to assess the resources that a company or utility invests in their measurement based programs. This cost includes the facility and labor costs, equipment and training, and general upkeep as well as other measurement-related functions, such as field testing, etc. This is a cost that, when projected nationwide, would be an important part of the economic infrastructure. However, the responses to these questions were insufficient for a broad generalization.

3.4 "What-If" Value Analysis

Before/After versus What If?

In terms of economic value, the ideal way in which to evaluate the NIST calibration service would be to evaluate the economics of a particular sector with and without the service being available. This evaluation has been possible for similar impact studies for other areas of calibration and measurement. For example, for the recently emerging area of fiber optics, the area was assessed ***before*** the NIST calibration service became available. This was a relative young area that began maturing in the absence of effective and appropriate NIST calibration support. ***After*** the need for a NIST calibration service was determined and the service established, the productivity and economics were examined again. Using the "before" and "after" comparisons, cost savings could be clearly evaluated that were due to the NIST calibration service for that area.

When examining a mature industry, such as the electric power industry, meaningful "before-and-after" data are not obtainable. The NIST calibration service in support of the electric power industry has been in existence for nearly a century. Instead of using the "before-and-after" analysis, an approach of a hypothetical "with and without" analysis was considered. Participants were asked to respond to an idea that was prompted by the question, "*What if NIST were to discontinue offering this calibration service?*" In assessing this hypothesis, economic aspects were to be considered for each participant to help gain insight and data. "*How much would it cost your company if NIST were to discontinue this service?*" The results of these responses would then be used then to assess how much is saved by industry by having access to the NIST Calibration Service for Electric Power and Industry. This question, however, turned out to be the least successful in yielding consistent and comparable answers, if any.

Narratives requested but few collected

Also, a narrative was requested asking for examples of when having NIST traceability and a solid base of measurements has saved the company money. Only a few anecdotes were obtained, and no reliable generalization can be developed in this report. However, those anecdotes that were recited expressed positive attitudes, and no respondent took the opportunity of the survey to express negative attitudes.

4. SELECTED RESULTS

Since this report focuses on technical impact and the economic impact aspects are effectively dealt with in the referenced Link report, no comprehensive analysis of the survey returns was performed. Instead, some selected results and responses are presented in this section, providing illustrations and anecdotes on this aspect of the electric industry and the perceived value of the NIST services for power and energy calibration.

4.1 Number of Meters Tested by the Utilities

The Utility Questionnaire asked the question, *"How many meters were tested and calibrated annually."* Thirty four of the participating utilities responded to this question. These 34 utilities represent the following approximate shares of number of utilities, energy sales, revenue, and customers:

1% of the number of utilities;
38% of energy sales;
39% of revenue;
34% of number of customers.

A total of 1,570,430 meters was reported as tested and calibrated by these 34 utilities. The distribution of the number of utilities suggested that these utilities represented a valid sample of the overall population of utilities. Using weighted analysis projection methods, an estimate of the national total number of meters tested and calibrated by all U.S. utilities was as follows:

4.13 million meters, based on energy sales;
4.02 million meters, based on revenue;
4.65 million meters, based on number of customers.

Four million watthour meters are tested each year

The differences among these three bases are small, so that for practical purposes, a quotable number of meters tested and calibrated in by all U.S. utilities is 4 million meters. This number is believed to be correct to within ±0.5 million meters. It is interesting to compare this number of 4 million meters tested annually with the 110 million end-users cited in Table 1, each presumably having at least one meter on the premises. Taking out of the 4 million those meters needed for new construction, a conclusion would be that an installed meter is expected on average to perform for more than 30 to 40 years without receiving calibration.

4.2 Utility Savings Because of NIST Traceability

In some instances, having NIST traceability can lead directly to a cost savings. This is true, for example, when differences in measurement results are resolved and corrected by having traceability. It is also true in legal cases where litigation centers about measured quantities; having NIST traceability usually removes the basic question regarding accuracy of standards used to support the measurements.

The utility participants were asked to provide instances where it was known that having traceability led to a cost savings, and by how much. A narrative was also requested describing the circumstances. In many instances, the dollar savings resulting from having NIST traceability is undisputed, but the actual savings may be difficult to assess.

Only five of the participants provided cost saving data. These represent the following shares of the national of the national of the utility industry:

Only five participants provided dollar figures for the savings

0.16% of the number of utilities;
8.5% of the energy;
6.8% of the revenue;
2.7% of the number of customers.

The distribution of respondents consisted of one large Government utility, one large investor owned utility, two medium sized investor owned utilities, and one small investor owned utility. Here again, the limited number of responses made it difficult to present valid economic information, hence the alternative approach taken by Link in assessing the economic impacts.

4.3 Examples of utility narratives

The last part of the questionnaire invited respondents to relate examples of occurrences where the NIST services, either directly or indirectly, solved problems or saved money. Not many respondents provided such stories; among those who did, the following six are representative:

Some happy stories

We have no stories to tell. We do, however, believe that NIST services are valuable in maintaining integrity and reputation in the community. We like it the way it is.

New meters is a good example. We test only 5% of the new single-phase residential meters, which saves the company 95% test time. The reason we can justify this sampling is that the Commissions accept this practice because we are traceable to NIST.

More happy stories

While I myself have no "stories" to relate to you I certainly can vouch for the fact that your service saves our company both time and money. We maintain traceability to NIST by participating in the Round Robin Testing as well as sending our units to you for calibration semi-annually. We feel if we had to use independent laboratories both our turnaround time and service per capital would suffer.

Using NIST traceable standards, we are able to perform in-house power/energy calibrations at our nuclear power plant that meet the NRC regulations. Largely due to NIST traceability and product improvements, sample testing, variable interval testing, selective testing is now possible. An estimate of the total of these savings is $70,000 per year.

We cannot recall any particular instance of being challenged with regard to traceability of our test equipment to the national standard. We have in the past tested the standards used by our regulatory agencies and have had good agreement with them.

Our standards are presently traced to NIST through the state PSC engineering staff for wattmeters accuracies. Over the years, several shipments of single-phase meters have been received with LL or FL out of our band of ± 0.3% "as-found" tests. Traceability required the manufacturer to recalibrate several pallets of earmarked meters. This involved several thousand dollars in labor costs.

4.4 Perceived Value of NIST Services to Utilities

Ranking utilities perceptions

The participants were requested to give a relative ranking to the value they see in the NIST services, described by nine statements. The instructions given allowed either giving a rank to all nine, or giving a rank to only those statements applicable to the particular utility. Table 3 shows the result of compiling the returns, where 100 is the most valuable level (rank 1) cited by the respondents, with zero being either of no value or the block for that question left blank (many utility respondents did not go beyond ranking the first few of the nine items).

Mandatory requirement and equity-in-trade are the major factors

Table 3 - Ranking of values attributed by utilities to NIST calibration services

Specific reason for value attributed to the services	Value score
Required by PUC or PSC, or other regulatory body	100
Helps to ensure equity-in-trade between our company and all customers	70
Helps to ensure equity-in-trade between our company and other utilities at power-pool interties or grid tie-points	45
Desire or require an authoritative and impartial calibration source	30
Helps to maintain good company image and improves overall public relations	25
Places company in stronger position in cases of potential litigation or disputes	25
Minimizes costs and differences when dealing with suppliers and vendors	20
Enhances capability to evaluate new products effectively	15
Require traceability because we calibrate standards for other parties	15

4.5 Value of NIST Services to PUCs

Ranking PUC perceptions

From the 19 public utility Commissions queried, 17 provided information in reply to the various questions. Economic information was generally scarce, but the question on perceived value, similar to that proposed to utilities, produced interesting returns on the perceived value and ranking of the NIST services. Table 4 shows the result of compiling the returns, where 100 is the most valuable level (rank 1) cited by the respondents, with zero being either of no value or the block for that question left blank (many PUC respondents did not go beyond ranking the first few of the ten items).

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Avoid duplication of efforts and provide help for referee role

Table 4 - Ranking of values attributed by PUCs to NIST calibration services

Specific reason for value attributed to the services	Value score
Utilities traceability to national standards makes it unnecessary for Commission to maintain its own reference standards	100
Places Commission in stronger position in cases of referee measurement	75
Helps to maintain good public image and improve overall public relations	70
Needed by Commission to calibrate or support Commission's own reference standards	65
Requires traceability because Commission calibrates standards for utilities or other parties	55
Not required or needed by Commission	55
Desire or require an authoritative and impartial calibration source	45
Required by PUC, PSC, or other State agency for their rules or regulations for electric utilities	45
Minimizes Commissions cost and differences when dealing with utilities or utility customers	40
Enhances capability to evaluate new products effectively	15

5. CONCLUSIONS

Clearly, the watthour meter is an essential instrument for both electric utilities and their customers - every one of the 100-plus million end-users. While the cost of the instrument itself is not a large economic factor, even if 4 million of them are produced annually, the economic aspects of their calibration are important industry and consequently to the NIST organization involved in maintaining the standards necessary for calibration.

The information returned by the respondents to the NIST survey attempting to assess the economic impact of the meter calibration services was not sufficiently comprehensive and consistent to allow broad generalization leading to a reliable assessment. However, the technical impact of these services was sufficiently documented to present this report describing the infrastructure and the relationships among the stakeholders.

A very clear message emerged from the responses by the four groups of participants (electric utilities, meter and instrument manufacturers, test laboratories, and public utility commissions), stating the importance of traceability to the NIST standards.

Some of the survey responses contained narrative anecdotes in response to a request for examples of savings made possible by the availability of the NIST calibration services. Deriving generalizations from a few qualitative anecdotes would be inappropriate, but a significant point is that all these were recited in positive terms, and no respondent took the opportunity of the survey to express negative attitudes.

APPENDIX
IMPACT STUDY QUESTIONNAIRES

The principal tool employed to gather information was a set of questionnaires designed to obtain quantitative information about two important aspects of the study. The first aspect was concerned with the size and the economics of the electric power industry in the limited sense of measurements, testing, and calibration. The second aspect was related to the "value" of the NIST Power and Energy Calibration Services, as perceived by the participants.

Each group of questionnaires was customized for the four study participant groups selected for this study. The groups, arranged in the expected approximate descending order of economic magnitude, are:

- Electric utilities
- Meter and instrument manufacturers
- Commercial testing and metrology laboratories
- State Public Utility Commissions

The general questions asked each group were basically the same. The phrasing and terminology, however, were made applicable for each group. For example, in trying to determine the "size" of each participant in terms of "calibration and measurement activity", utilities were asked "How many meters are tested?", whereas meter manufacturers were asked "How many meters were manufactured?", and the Public Utility Commissions were asked "How many tests were performed or witnessed?". In a few instances, a question appropriate for one group would not apply to another group. In such cases the question was omitted where it did not apply.

An important element of the Impact Study was the participant's perceived value of the NIST Calibration Service for Power and Energy. To evaluate this, a question having multiple-choice responses was asked of each participant. The responses were tailored for each participant group. The participants were asked to rank numerically the importance of the appropriate responses. The candidate responses had been formulated from information that NIST calibration clients had previously shared and from sample preliminary questionnaires used to help formulate the questionnaire and test its effectiveness.

Copies of the four customized questionnaires, as approved by the Office of Management and Budget, are included in this Appendix.

Impact Study for NIST Electrical Power and Energy Calibration Service

National Institute of Standards and Technology
Electronics and Electrical Engineering Laboratory
Gaithersburg, Maryland

The Electronics and Electrical Engineering Laboratory (EEEL) of the National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards (NBS), is conducting a study to evaluate the value and effectiveness of selected NIST calibration services. For this study, the service utilizing the electrical standards of power and energy (watt, watthour, var, and varhour) has been selected.

Information for this study is being gathered from a sampling of the electric power industry, and private and public organizations that utilize this NIST calibration service. The combined responses from electric utilities, meter manufacturers, instrument manufacturers, independent testing and metrology laboratories, and State public service commissions will enable NIST to assess the value and economic impact of this calibration service throughout the nation. The findings of this impact study will be used to guide future NIST program efforts. The results should be of interest also to the electric power industry and to those who contribute related measurement support to this industry.

Your Commission has been chosen to participate in this study because it is believed that it derives benefits from this NIST service, either directly or indirectly. Responding to the attached questionnaire will be appreciated and assist NIST in completing this study. Your participation is voluntary.

Please return your completed questionnaire and any narrative comments to:

National Institute of Standards and Technology
John D. Ramboz
Electricity Division, MET B344
Gaithersburg, MD 20899

Your response would be appreciated by October 11, 1991. Thank you.

GENERAL INFORMATION AND INSTRUCTIONS

The information requested by the attached questionnaire covers three areas:

- Economic data that describes costs related to calibration, testing, and other operational costs for your Commission,
- "Non-economic" data that assess importance and value of the NIST calibration service to your operations, and
- Narrative information that describes instances when having traceability and indisputable measurements have saved your Commission time and money.

Most of the "non-economic" questions are answerable by multiple choice and should be easy and quick to answer. The questions that require economic related answers may require more effort, depending on whether you have direct access to this information, or have to research it. In any case, it is felt that no more than a couple of telephone calls within your organization should make the data requested available to you.

Questions 10 and 11 will likely provoke some thought. These questions ask,"if the NIST Power and Energy Calibration Service were no longer offered, how would this impact your operations. What is the impact and cost to you?" It will require you to do some intelligent guessing. Reasonable estimates are acceptable for the responses to these questions....it is recognized that there are variables and estimates involved in answering these two questions.

Question 12 asks for narratives that describe instances when NIST traceability or indisputable measurements has saved money for your Commission. Is there an estimate of cost savings to your company as a result of traceable measurements and calibration? This information would be useful.

Please complete the information below or attach your business card:

Commission: ______________________________

Mailing Address: ______________________________

____

____

Name and title of person(s) completing this questionnaire:

____

Phone No.: (   )   -   FAX No.: (   )   -

Would you like to receive a copy of the final report when available?

☐ Yes ☐ No

ELECTRIC UTILITIES

1. What are the principal reasons that dictate your needs for NIST calibration, or measurement traceability to NIST (for quantities of power and energy, specifically for the watt, watthour, var, and varhour)? Please rank numerically, using numeral 1 to indicate the most important, 2 to indicate next most important, and so forth. If statement does not apply to your operations, leave blank. Add any unlisted reasons and rank relative importance. Consider reasons collectively.

Relative Ranking

a. ☐ Required by State Public Utility Commission, Public Service Commission, or other State or Federal Regulatory body.

b. ☐ Helps to ensure equity-in-trade between our company and other utilities at power-pool interties or at connections to the electric power grid.

c. ☐ Helps to ensure equity-in-trade between our company and all customers.

d. ☐ Places company in stronger position in cases of potential litigation.

e. ☐ Minimizes costs and possible differences when dealing with suppliers and vendors.

f. ☐ Helps to maintain good company image and improves overall public relations.

g. ☐ Enhances capability to evaluate new products effectively.

h. ☐ Desire or require an authoritative and impartial source of calibration.

i. ☐ Require traceability because we calibrate standards for other parties.

j. ☐ Other: ____________________

____

2. What was the sales revenue for electric energy sold by your company in 1989?

Sales revenue, 1989: $ __________

3. How much electric energy (in kWh) was sold by your company in 1989? :

Total energy sold, 1989: ____________ kWh

4. Number of meters purchased (1989) that your company uses directly in support of power and energy measurements (include single-phase, polyphase, watt, watthour, var, varhour, kVA, demand, etc.) :

_________ meters

5. All meters tested and calibrated, both in your meter laboratory and in the field (1989):

_________ meters

6. Indicate the testing basis by which you accept <u>new meter</u> purchases:

a. ☐ 100% Testing, all new meters

b. ☐ Sample Testing, new single phase meters; portion sampled: _______%

c. ☐ Sample Testing, new polyphase meters; portion sampled: _______%

d. ☐ None

e. ☐ Other; please briefly explain: ________________________________

____

7. Where does your company submit its power and energy standards to for periodic calibration?

a. ☐ Sends standards to NIST b. ☐ Uses NIST MAP Service

c. ☐ Sends standards to manufacturer of standard

d. ☐ Sends standards to independent standards laboratory

e. ☐ Other: Briefly describe: ________________________________

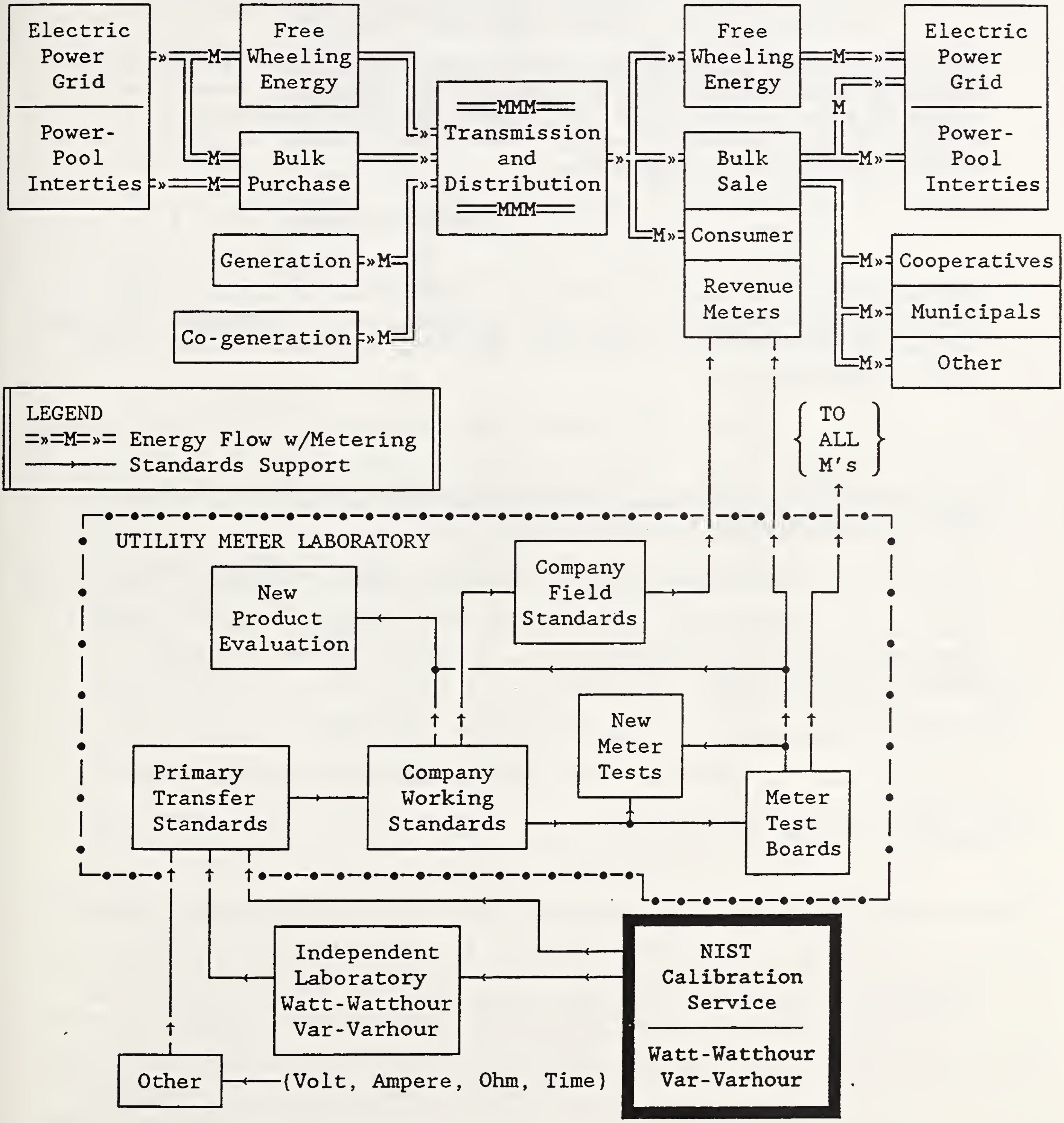
____

8. Figure 1 on the following page shows the company metering which is supported by the meter and/or standards laboratory and by NIST calibrations. Does this generally illustrate the structure and operation of your company? If no, change appropriately or make suitable notation.

a. ☐ Yes b. ☐ No

Figure 1
Revenue Metering Supported by NIST Power and Energy Calibration Services for a Typical Utility

Measurement traceability achieved by direct or indirect use of the NIST Power and Energy Calibration Services (i.e., watt, watthour, var, and varhour calibrations).



9. What does it cost your company to maintain and operate the meter and/or metrology (standards) laboratory? If operated at separate locations and budgets, please combine. Include field measurements. Incorporate your total budget for all testing and calibrations (beyond the watt, watthour and var, varhour functions). Consider your operating budget, capital equipment, and related costs:

Total annual operating cost, 1989: $ __________

Does the response to question 9 above reflect any unusual circumstances, such as new facilities, fire or flood damage, laboratory consolidation, change of ownership, etc.? If YES, please adjust your estimate appropriately to project (looking forward) to a typical or normal year without the unusual circumstances.

Adjusted operating cost: $ __________

10. What portion of the overall laboratory costs given in response for question 9 above supports just watt, watthour, var, and varhour metering? Include costs related to time-of-use metering, recorders, demand, kVA, repair, adjustment, etc.

Portion for related power and energy effort: __________%

11. How much do you spend annually for the calibration of your standards by NIST or other sources of calibration?:

Cost of calibrating power and energy standards: $__________

12. Does or has your laboratory derived the watt, watthour, var, or varhour from basic electrical standards (i.e., from the voltage, current, impedance, phase angle, and time)?:

a. ☐ No, never have

b. ☐ Not now, but used to

c. ☐ No, but we would like to

d. ☐ Yes, still do

e. ☐ Yes, but we would like to quit

If you checked "c" or "d", can you briefly give the benefits to your company?:

____

____

____

____

If you answered "b" or "e", what are the reasons for changing? Check all appropriate reasons. Indicate if a strong or weak reason.

Reason		
Strong	Weak	
f. ☐	☐	More cost effective to buy the service from NIST or other standards laboratory than to do it ourselves.
g. ☐	☐	Present measurement accuracies now make it technically difficult to derive the watt, watthour, var, and varhour ourselves with sufficient accuracy to meet our needs.
h. ☐	☐	Do not have the equipment, technical staff, management, budget, or training to derive and maintain our own power and energy standards to accuracies needed.
i. ☐	☐	Other (please describe briefly): ______________________

13. One way to evaluate the effectiveness and value of the NIST Calibration Service for electrical power and energy (viz., watt, watthour, var, and varhour) is to examine your laboratory operational and capital equipment costs IF this particular NIST Calibration Service were no longer available. (This is only a hypothetical exercise; NIST does not have plans to discontinue this Service.) What would you do? How would it impact your operations? What would it cost your company?

Contrasted to Figure 1 which shows the utilities traceability by making direct use of the NIST Calibration Service for electric power and energy (viz., watt, watthour, var, and varhour), Figure 2 on the following page instead shows traceability directly to NIST Calibration Services for voltage, current, impedance, phase angle, and time.

Measurement traceability to basic national standards could be achieved by use of one of two paths to NIST Calibration Services for basic standards (i.e., voltage, current, impedance, phase angle, and time):

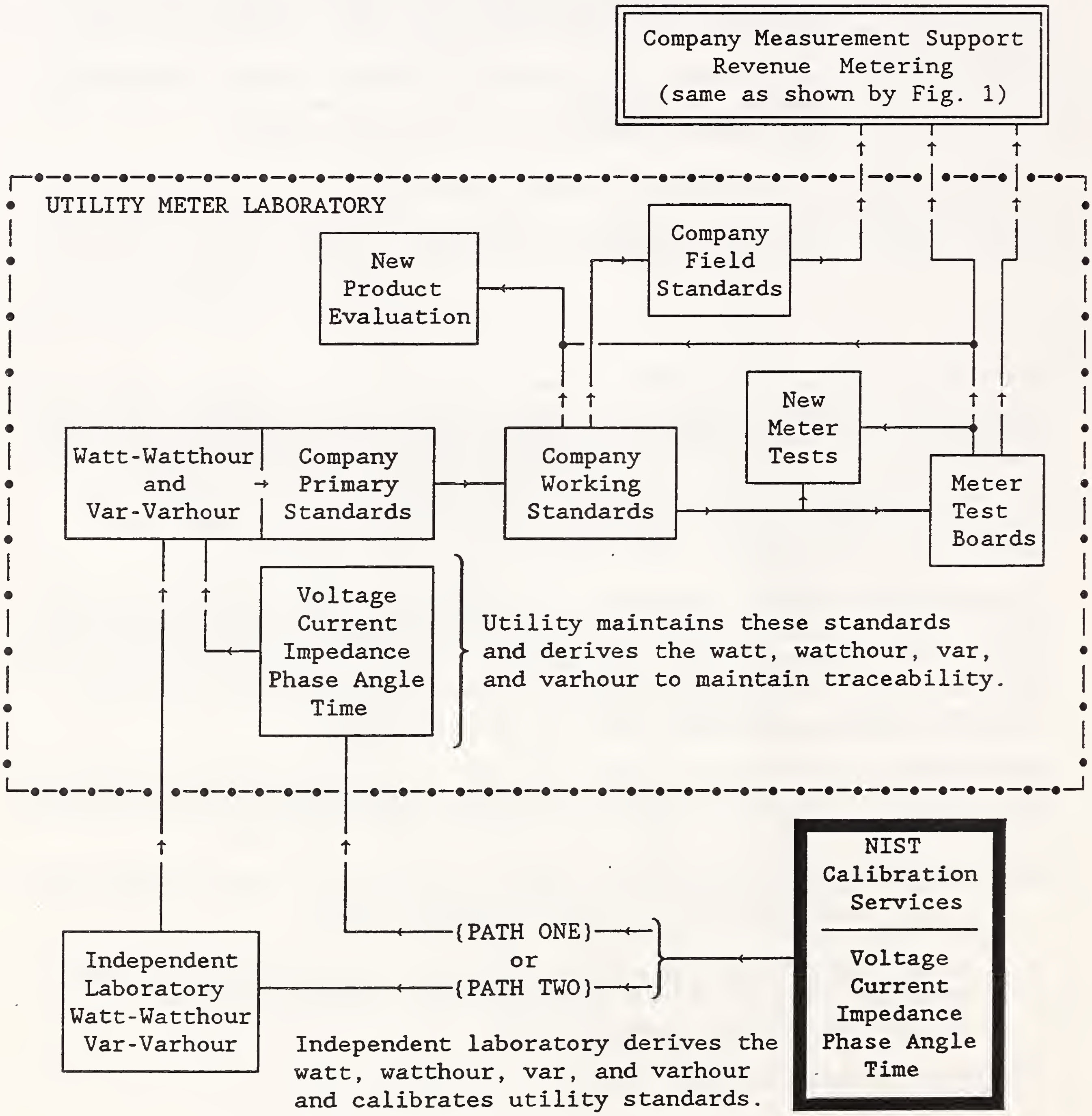
- Using PATH ONE, the utility would be required to derive power and energy standards from the basic standards shown.
- Using PATH TWO, an independent laboratory would derive the watt, watthour, var, or varhour, which in turn, would provide a calibration service to the utility.

CONTINUED ON PAGE FOLLOWING FIGURE 2....

Figure 2

Revenue Metering Supported by the Use of Basic Standards to Derive Utilities Own Units of Power and Energy

Measurement traceability achieved by use of one of two paths to NIST Calibration Services for basic standards (i.e., voltage, current, impedance, phase angle, and time). Using PATH ONE, the utility is required to derive power and energy standards from the basic standards shown. Using PATH TWO, an independent laboratory derives the watt, watthour and var, varhour, which in turn, provides a calibration service to the utility.



14. From Figure 2, which path would seem to best suit your operations? Remember that if you select to maintain traceability through "Path Two", NIST will also not offer the independent laboratory power and energy calibrations, but just the basic electrical calibrations for voltage, current, impedance, phase angle, and time.

a. ☐ Path One   b. ☐ Path Two   c. ☐ Other

If "other" was selected, can you briefly describe?: ________________

____

____

15. Using the path(s) selected above, and remembering the accuracy needs of your laboratory, what would be your estimated <u>increased cost</u> for establishing and maintaining traceability in the absence of the present NIST Power and Energy Calibration Service? It might be useful to consider some of the following and how they might affect your operational costs:

The possible need for:

Added technical staff (consider also the technical level)
Increased managerial time and effort
Additional laboratory space and new capital equipment
Calibration and maintenance of new equipment
Training, travel
Additional shipping of standards, insurance
New record keeping and related paper work
Increased intercomparisons with neighboring utilities

Possible consequences might be:

Trade-offs and comprises in achieving needed accuracies
Possible loss of measurement accuracy
Disagreements in acceptance tests of new meters
Increased interactions with your Public Utility Commissions
Weaker position in cases of litigations or disputes
Increase possibility of inequality-in-trade

a. Initial increased cost for establishing new calibration capability:

$ __________

b. Annual increased cost for establishing and maintaining traceability after initial costs have been absorbed:

$ __________

CONTINUED ON NEXT PAGE...

16. Can you provide a narrative below that describes instances when NIST traceability, your calibration and standards, or other measurements for power and energy have solved problems or saved money for your company? Examples might include resolving disagreements with vendors, customer complaints, tampering, power diversion, Public Utility Commission interactions, cases of litigation, system efficiency determinations, and so forth. (Your "story" should be related to measurements dealing with the quantities; watt, watthour, var, varhour, demand, kVA, etc.) Attach seperately if more convenient

a. Dollar amount of savings: $ __________

These savings were a result of:

b. ☐ NIST traceability (direct or indirect)

c. ☐ Company calibration and standards

*** THANK YOU FOR YOUR TIME AND EFFORT IN COMPLETING THIS QUESTIONNAIRE ***

[10-30-90]

PUBLIC UTILITY COMMISSIONS

1. With regard to metering accuracy, does the wording of your regulations contain references to traceability or to one or more of the following:

   a. ☐ To "national standards,"

   b. ☐ To the National Institute of Standards and Technology, NIST, the National Bureau of Standards, NBS, or Bureau of Standards,

   c. ☐ To the American National Standards Institute, ANSI, "C12", or American National Standard Code for Electricity Metering C12,

   d. ☐ "Traceable measurements" without specific reference to where the measurements are traceable to,

   e. ☐ No specific reference to standards.

   e. ☐ Other: Briefly describe: ______________________________

   ____

   ____

   ____

   ____

***** N O T E *****

If possible, please enclose a copy of the pages of your Commissions rules and regulations that make reference to traceability requirements, or the above phrases as answered in Question 1 above.

2. Does your Commission or other State Agency have regulatory authority for submetering installations, such as multiple tenant housing, apartments, trailer parks, marinas, shopping centers, etc.?

   ☐ Yes ☐ No

   If yes, what is the approximate percentage of revenue, electricity usage, or other measure of size in comparison to the total for the State.

   Percentage of the State total that submetering represents: __________ %

3. Please rank the value of the existence and availability NIST Power and Energy Calibration Services (for quantities of power and energy, specifically for the watt, watthour, var, and varhour) in supporting your Commission's regulatory, compliance, or other responsibilities?

- Please rank numerically, using numeral 1 to indicate the most important, 2 to indicate next most important, and so forth. If choices are equally important, use the same numerical ranking.
- If statement does not apply to your operations, leave blank.
- Add any unlisted reasons and rank relative importance.
- Consider choices collectively.

Relative Ranking

a. ☐ Requirement by Public Utility Commission or Public Service Commission, or other State Agency, for their rules or regulations for electric utilities.

b. ☐ Needed by Commission to calibrate or support Commission's own reference standards.

c. ☐ Utilities traceability to national standards makes it unnecessary for Commission to maintain its reference standards.

d. ☐ Places Commission in stronger position in cases of referee measurements, considering that either or both the Commission and the utility has traceability to NIST.

e. ☐ Minimizes Commissions costs and possible differences when dealing with utilities or utility customers.

f. ☐ Helps to maintain good public image and improves overall public relations.

g. ☐ Enhances capability to evaluate new products effectively.

h. ☐ Desire or require an authoritative and impartial source of calibration.

i. ☐ Require traceability because Commission calibrates standards for utilities or other parties.

j. ☐ Not required or needed.

k. ☐ Other: ______________________________

____

4. Does your Commission get involved in performing, participating in, or observing referee measurements in cases of utility customer complaints or disputes?

a. ☐ Yes   b. ☐ No

If yes, approximately how many such tests are performed in a typical one-year period?:

c. Number of referee tests in a typical year: __________ tests

d. If reimbursed, what is a typical amount: $ __________

e. Does measurement traceability ultimately to NIST, either directly or indirectly, have a positive impact in the results of such referee measurements?

☐ Yes   ☐ No

If the answer to e above was yes, please provide a short narrative that summarizes the nature of the advantages of undisputable measurements, and a cost savings because of having traceability:

____

____

____

____

____

____

5. Does your Commission own and maintain reference standard meters (wattmeters, watthour meters, transducers, etc.) for its use in working with utilities, or utility customers? (Consider those reference standards that are in use on a regular basis.)

a. ☐ Yes   b. ☐ No

IF YOUR ANSWER IS <u>NO</u> AND YOUR COMMISSION <u>DOES NOT</u> OWN OR MAINTAIN ITS OWN REFERENCE STANDARDS THAT REQUIRE CALIBRATION, SKIP AHEAD TO QUESTION 12.

IF YOUR ANSWER IS <u>YES</u>, PLEASE CONTINUE ON THE FOLLOWING PAGE...

If yes, please indicate the number of meters or transducers used as standards below. Include both laboratory and field standards.:

c. Number of wattmeters: ____________

d. Number of watthour meters: ________

e. Number of varmeters: _____________

f. Number of varhour meters: _________

g. Number of multifunction watt and watthour meters: __________

h. Number of multifunction var and varhour meters: ___________

i. Other (please describe): ______________________________

____

6. If your Commission owns its reference standards, where are they submitted for periodic calibration? Check more than one if applicable.

a. ☐ Send standards directly to NIST

b. ☐ Derive the units of power and energy (i.e., the watt, var, watt, and watthour) from basic electric standards of voltage, current, impedance, phase angle, and time.

c. ☐ Send standards to manufacturer of standard

d. ☐ Send standards to independent standards laboratory

e. ☐ Rely on the original manufacturers calibration

e. ☐ Other: Briefly describe: ______________________________

____

____

7. What is the estimated typical annual cost your Commission to maintain and operate the meter and/or metrology (standards) laboratory, or to maintain its reference standards for electric power and energy? If operated at separate locations and budgets, please combine. Incorporate your <u>total</u> budget for <u>all</u> electrical testing and calibrations that deal with power and energy. Consider your operating budget, capital equipment, and related costs.

Estimated total annual operating cost: $ ___________

8. How much do you spend annually for the calibration of your electric power and energy standards by NIST or other sources of calibration?:

Cost of calibrating power and energy standards: $__________

9. Does your laboratory derive the watt, watthour, var, or varhour on a regular basis from basic electrical standards (i.e., from voltage, current, impedance, phase angle, and time)?:

a. ☐ No, never has
b. ☐ Not now, but used to
c. ☐ No, but we would like to
d. ☐ Yes, still does
e. ☐ Yes, but we would like to quit

If you checked "c" or "d" above, can you briefly describe the benefits to your Commission?: ____________________

____

____

____

If you answered "b" or "e" in response to question 9 above, what are the reasons for changing? Check all appropriate reasons. Indicate if a strong or weak reason. If "Other", please describe briefly.

Reason: Strong	Reason: Weak	
f. ☐	☐	More cost effective to buy the service from NIST or other standards laboratory than to do it ourselves.
g. ☐	☐	Present measurement accuracies now make it technically difficult to derive the watt, watthour, var, and varhour ourselves with sufficient accuracy to meet our needs.
h. ☐	☐	Do not have the equipment, technical staff, management, budget, or training to derive and maintain our own power and energy standards to accuracies needed.
i. ☐	☐	Other (please describe briefly): ____________________

____

____

____

10. One way to evaluate the effectiveness and value of the NIST Calibration Service for electrical power and energy (viz., watt, watthour, var, and varhour) is to examine your operational and capital equipment costs IF this particular NIST Calibration Service were no longer available. (This is only a hypothetical exercise; NIST does not have plans to discontinue this Service.) What would you do? How would it impact your operations? What would it cost your Commission?

Contrasted to direct NIST traceability by your Commission, or from an independent standards laboratory which makes direct use of NIST Power and Energy Calibration Services (viz., watt, watthour, var, and varhour), instead consider a chain of traceability relying on the NIST Calibration Services for only voltage, current, impedance, phase angle, and time.

Measurement traceability to basic national standards could be achieved by use of one of two paths to NIST Calibration Services for basic standards (i.e., voltage, current, impedance, phase angle, and time):

- PATH ONE; your Commission would be required to derive power and energy standards from the basic standards shown, or

- PATH TWO; an independent laboratory would derive the watt, watthour, var, or varhour, which in turn, would provide a calibration service to your Commission.

Which path would seem to best suit your operations? Remember that if you select to maintain traceability through "Path Two", NIST will also not offer the independent laboratory power and energy calibrations, but just the basic electrical calibrations for voltage, current, impedance, phase angle, and time.

a. ☐ Path One b. ☐ Path Two c. ☐ Other

If "other" was selected, can you briefly describe?: ________________

____

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11. Using the path(s) selected above, and remembering the accuracy needs of your Commission, what would be your estimated increased cost for establishing and maintaining traceability in the absence of the present NIST Power and Energy Calibration Service? It might be useful to consider some of the following and how they might affect your operational costs:

The possible need for:

Added technical staff (consider also the technical level)
Increased managerial time and effort
Additional laboratory space and new capital equipment
Calibration and maintenance of new equipment
Training, travel
Additional shipping of standards, insurance
New record keeping and related paper work

Possible consequences might be:

Trade-offs and compromises in achieving needed accuracies
Possible loss of measurement accuracy
Disagreements in complaint tests
Increase possibility of inequality-in-trade

a. Estimated initial increased cost for establishing new calibration capability:

$ __________

b. Estimated annual increased cost for establishing and maintaining traceability after initial costs have been absorbed:

$ __________

12. Can you provide a narrative that describes instances when measurements or calibrations traceable to NIST, either directly or indirectly, have solved problems or saved money for your Commission? This can relate to either traceability of your reference standards, or the traceability of utility owned reference standards. (Your "story" should be related to measurements dealing with the quantities; watt, watthour, var, varhour, demand, kVA, etc.) Attach separately if more convenient.

____

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Continued on following page...

a. Estimated dollar amount of savings: $ __________

These savings were a result of:

b. ☐ NIST traceability (direct or indirect)

c. ☐ Commission calibrations and standards

d. ☐ Utilities calibrations and measurements

13. Any other comments that you feel would be useful in understanding the role and operation of your Commission by NIST in completing this study:

*** THANK YOU FOR YOUR TIME AND EFFORT IN COMPLETING THIS QUESTIONNAIRE ***

M E T E R & I N S T R U M E N T M A N U F A C T U R E R S

1. What are the principal reasons that dictate your needs for NIST calibration, or measurement traceability to NIST (for quantities of power and energy, specifically for the watt, watthour, var, and varhour)? Please rank numerically, using numeral 1 to indicate the most important, 2 to indicate next most important, and so forth. In cases of equal importance, use the same numerical ranking. If statement does not apply to your operations, leave blank. Add any unlisted reasons and rank relative importance. Consider reasons collectively.

Relative Ranking

a. ☐ Required by State Public Utility Commission, Public Service Commission, or other State or Federal Regulatory body.

b. ☐ Customers require NIST traceability. Without traceability, our ability to compete in the market place would be hampered.

c. ☐ Helps to ensure equity-in-trade between our company and all customers.

d. ☐ Places company in stronger position in cases of potential litigation.

e. ☐ Minimizes costs and possible differences when dealing with customers.

f. ☐ Helps to maintain good company image and improves overall relations with customers.

g. ☐ Enhances capability to develop new products effectively.

h. ☐ Desire or require an authoritative and impartial source of calibration.

i. ☐ Require traceability because we calibrate standards for other parties.

j. ☐ Other: ____

____

2. What was the revenue for electric meters or instruments (power and energy) from sales by your company in 1989?

Sales revenue, 1989: $ ___________

3. How many electric meters or instruments (power and energy) were sold by your company in 1989? (include single-phase, poly-phase, watt, watthour, var, varhour, kVA, demand, etc.):

Total meters or instruments sold, 1989: _____________ meters

4. Where does your company submit its power and energy standards for periodic calibration?

a. ☐ Sends standards to NIST   b. ☐ Uses NIST MAP Service

c. ☐ Sends standards to manufacturer of standard

d. ☐ Sends standards to independent standards laboratory

e. ☐ Other: Briefly describe: ____

____

____

____

____

5. Figure 1 on the following page shows the company metering which is supported by the meter and/or standards laboratory and by NIST calibrations. Does this generally illustrate the structure and operation of your company?

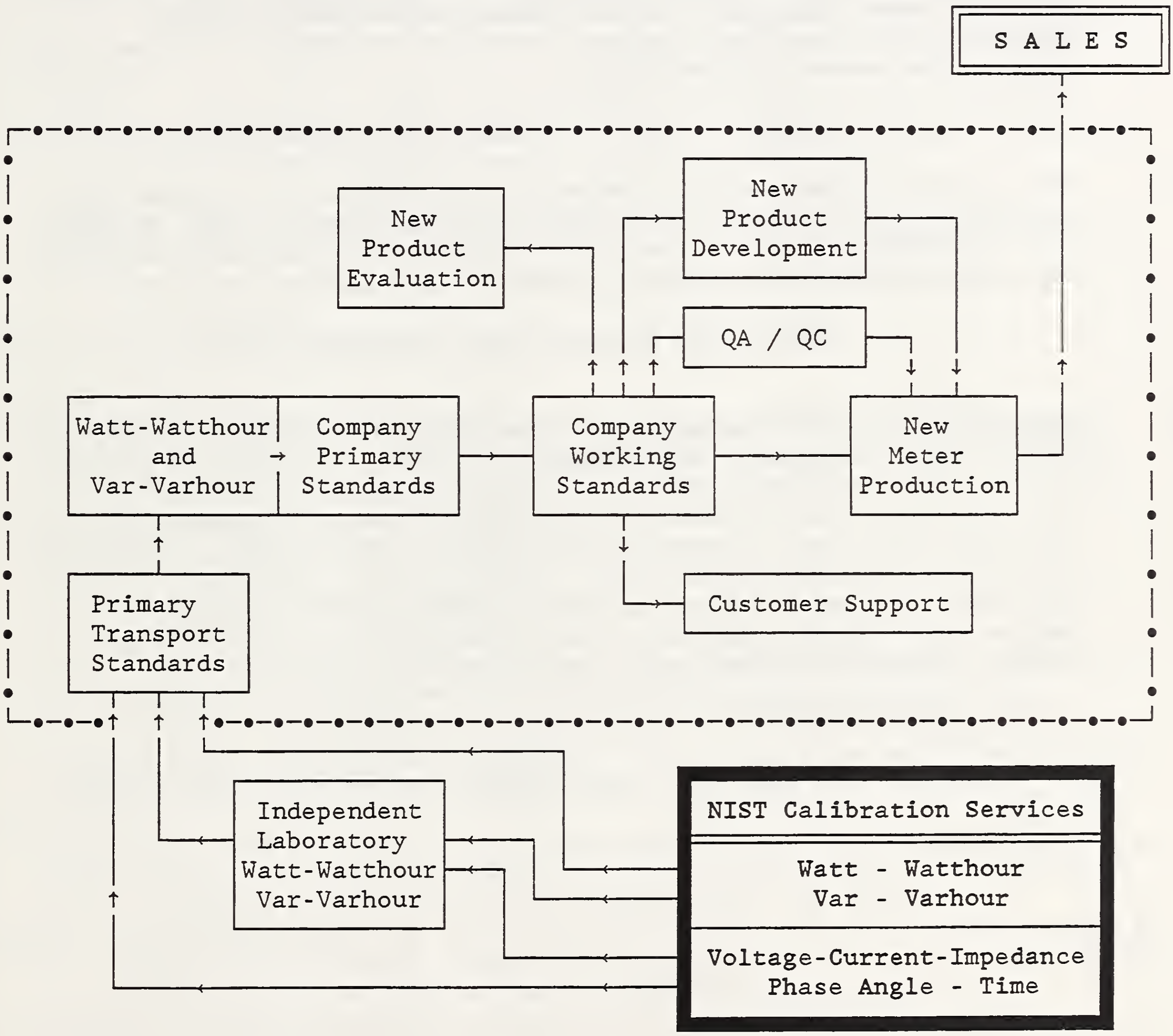
a. ☐ Yes   b. ☐ No

If your response above was no, please change the drawing appropriately, if possible, or make suitable notation.

Figure 1

Typical Meter Manufacturing Supported by NIST Calibration Services

Measurement support within a typical meter manufacturing facility which supports manufacturing and production. Sources of traceability achieved by direct or indirect use of the NIST Power and Energy Calibration and other Calibration Services.



6. What does it cost your company to maintain and operate the meter and/or metrology (standards) laboratory? Incorporate your total budget for all testing and calibrations. If operated at separate locations and budgets, please combine. Consider your operating budget, capital equipment, and related costs:

Total annual operating cost, 1989: $ ___________

Does the response to question 6 above reflect any unusual circumstances, such as new facilities, fire or flood damage, laboratory consolidation, change of ownership, etc.? If so, please adjust your estimate appropriately to project (looking forward) to a typical or normal year without the unusual circumstances.

Adjusted operating cost: $ ___________

7. What portion of the overall laboratory costs given in response for question 6 above supports just power and energy (i.e., watt, watthour, var, and varhour) metering and calibrations? Include costs related to time-of-use metering, recorders, demand, repair, adjustment, etc.

Portion for related power and energy effort: ___________%

8. How much do you spend annually for the calibration of your standards by NIST or other sources of calibration?:

Cost of calibrating power and energy standards: $___________

9. Does your laboratory derive the watt, watthour, var, or varhour on a regular basis from basic electrical standards (i.e., from voltage, current, impedance, phase angle, and time)?:

a. ☐ No, never has
b. ☐ Not now, but used to
c. ☐ No, but we would like to
d. ☐ Yes, still does
e. ☐ Yes, but we would like to quit

If you checked "c" or "d" above, can you briefly describe the benefits to your company?:

____

____

____

____

If you answered "b" or "e" in response to question 9 above, what are the reasons for changing? Check all appropriate reasons. Indicate if a strong or weak reason. If "Other", please describe briefly.

Reason		
Strong	Weak	
f. ☐	☐	More cost effective to buy the service from NIST or other standards laboratory than to do it ourselves.
g. ☐	☐	Present measurement accuracies now make it technically difficult to derive the watt, watthour, var, and varhour ourselves with sufficient accuracy to meet our needs.
h. ☐	☐	Do not have the equipment, technical staff, management, budget, or training to derive and maintain our own power and energy standards to accuracies needed.
i. ☐	☐	Other (please describe briefly): ________________

10. One way to evaluate the effectiveness and value of the NIST Calibration Service for electrical power and energy (viz., watt, watthour, var, and varhour) is to examine your laboratory operational and capital equipment costs IF this particular NIST Calibration Service were no longer available. (This is only a hypothetical exercise; NIST does not have plans to discontinue this Service.) What would you do? How would it impact your operations? What would it cost your company?

Contrasted to Figure 1 which shows the traceability by making direct use of the NIST Calibration Service for electric power and energy (viz., watt, watthour, var, and varhour), Figure 2 on the following page instead shows traceability directly to NIST Calibration Services for only voltage, current, impedance, phase angle, and time.

Measurement traceability to basic national standards could be achieved by use of one of two paths to NIST Calibration Services for basic standards (i.e., voltage, current, impedance, phase angle, and time):

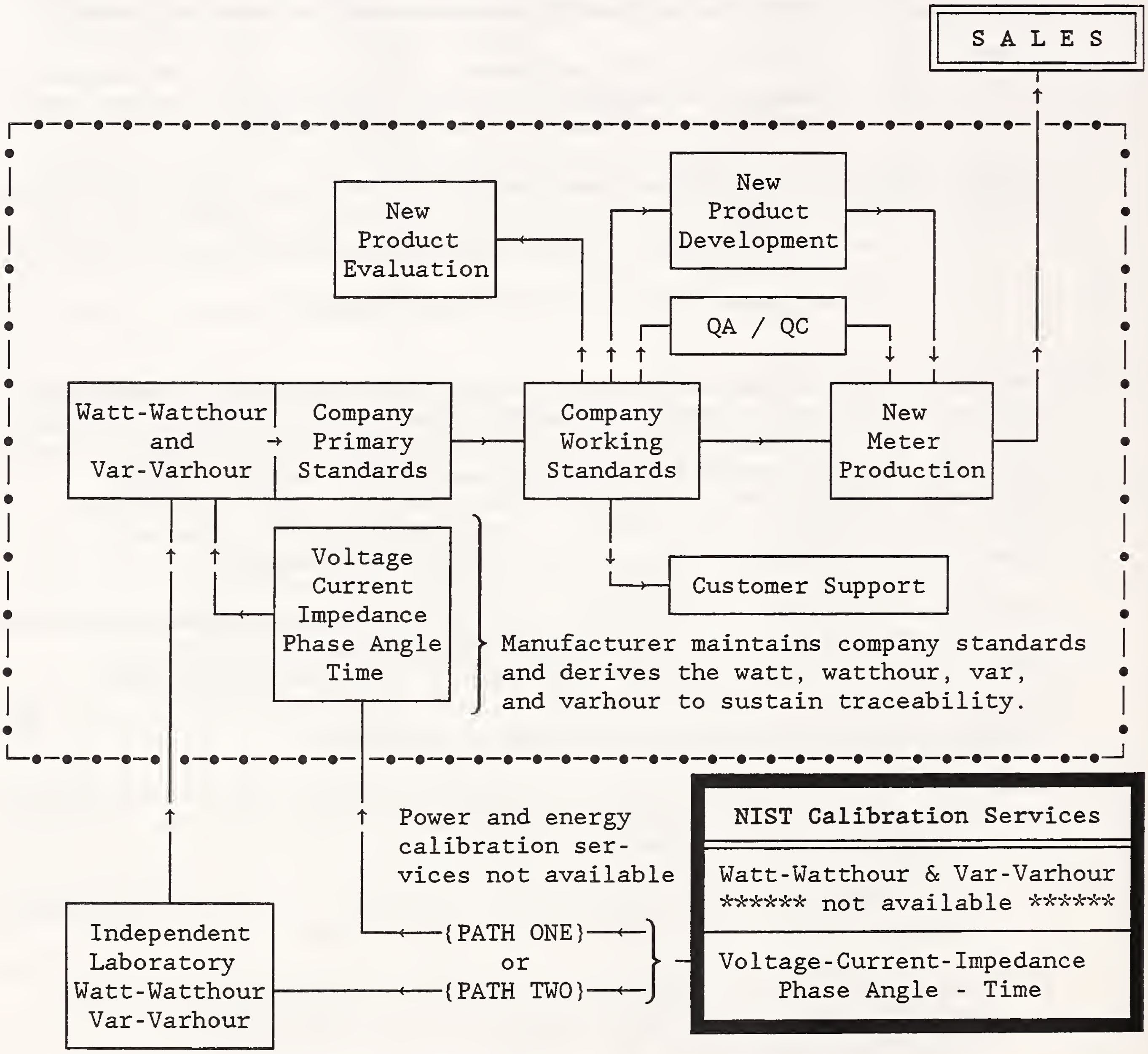
- Using PATH ONE, your company would be required to derive power and energy standards from the basic standards shown.

- Using PATH TWO, an independent laboratory would derive the watt, watthour, var, or varhour, which in turn, would provide a calibration service to your company.

CONTINUED ON PAGE FOLLOWING FIGURE 2....

Figure 2
<u>Meter Manufacturing Supported by the Use of Basic Standards to Derive Companies Own Units of Power and Energy</u>

Measurement traceability achieved by use of one of two paths to NIST Calibration Services for basic standards (i.e., voltage, current, impedance, phase angle, and time), assuming that NIST Power and Energy Calibration services were not available. Using PATH ONE, your company is required to derive power and energy standards from the basic standards shown. Using PATH TWO, an independent laboratory derives the watt, watthour and var, varhour, which in turn, provides a calibration service to your company. Compare to Figure 1.



Independent laboratory derives the watt, watthour, var, and varhour and calibrates company standards.

From Figure 2, which path would seem to best suit your operations? Remember that if you select to maintain traceability through "Path Two", NIST will also not offer the independent laboratory power and energy calibrations, but just the basic electrical calibrations for voltage, current, impedance, phase angle, and time.

a. ☐ Path One   b. ☐ Path Two   c. ☐ Other

If "other" was selected, can you briefly describe?: ________________

____

____

11. Using the path(s) selected above, and remembering the accuracy needs of your company, what would be your estimated <u>increased cost</u> for establishing and maintaining traceability in the absence of the present NIST Power and Energy Calibration Service? It might be useful to consider some of the following and how they might affect your operational costs:

The possible need for:

Added technical staff (consider also the technical level)
Increased managerial time and effort
Additional laboratory space and new capital equipment
Calibration and maintenance of new equipment
Training, travel
Additional shipping of standards, insurance
New record keeping and related paper work

Possible consequences might be:

Trade-offs and compromises in achieving needed accuracies
Possible loss of measurement accuracy
Disagreements in acceptance tests of new meters
Weaker position in cases of litigations or disputes
Increase possibility of inequality-in-trade

a. Initial increased cost for establishing new calibration capability:
$ __________

b. Annual increased cost for establishing and maintaining traceability after initial costs have been absorbed:
$ __________

CONTINUED ON NEXT PAGE...

12. Can you provide a narrative below that describes instances when NIST traceability, your calibrations and standards, or other measurements for power and energy have solved problems or saved money for your company? (Your "story" should be related to measurements dealing with the quantities; watt, watthour, var, varhour, demand, kVA, etc.) Attach separately if more convenient

a. Estimated dollar amount of savings: $ __________

These savings were a result of:

b. ☐ NIST traceability (direct or indirect)

c. ☐ Company calibrations and standards

*** THANK YOU FOR YOUR TIME AND EFFORT IN COMPLETING THIS QUESTIONNAIRE ***

NIST/EEEL Impact Study for
Electric Power and Energy Calibration Services

A Questionnaire for
COMMERCIAL TESTING AND METROLOGY LABORATORIES

1. Do you consider the existence and availability of the NIST Power and Energy Calibration Services important in supporting your Company's responsibilities ? (For quantities of power and energy, specifically for the *watt, watthour, var,* and *varhour.*)

   a. ☐ Yes b. ☐ No

2. Does your Company make use of the NIST Calibration Services for Power and Energy, either directly or indirectly?

   a. ☐ Yes b. ☐ No

   If answered yes, please provide a short narrative describing how your Company uses the calibration services (directly, indirectly, or both). Attach separately if more convenient.

   c. ☐ Directly d. ☐ Indirectly

   ____
   ____
   ____
   ____

3. What are the principal reasons that dictate your needs for NIST calibration, or measurement traceability to NIST, either directly or indirectly? Please provide a short narrative. Attach separately if more convenient.

   ____
   ____
   ____
   ____
   ____

4. Do you own power and energy standards, i.e., standard *wattmeters* or *watthour* meters or transducers? (Consider those that are in use on a regular basis.)

a. ☐ Yes b. ☐ No

If yes, please indicate the number of meters/transducers used as standards below. Include both laboratory and field standards.:

c. Number of *wattmeters*: ____________

d. Number of *watthour* meters: ________

e. Number of *varmeters*: _____________

f. Number of *varhour* meters: ________

g. Number of multifunction *watt* and *watthour* meters: ________

h. Number of multifunction *var* and *varhour* meters: __________

i. Other (please describe) : ____

____

5. Where do you submit your power and energy standards for periodic calibration?

a. ☐ Send standards directly to NIST.

b. ☐ Derive the units of power and energy (i.e., the watt, watthour, var, and varhour) from basic electric standards of voltage, current, impedance, phase angle, and time.

c. ☐ Send standards to manufacturer of standard.

d. ☐ Send standards to independent standards or metrology laboratory.

e. ☐ Rely on the original manufacturers calibration.

f. ☐ Do not have standards calibrated.

g. ☐ Other: Briefly describe: ____

____

____

____

6. How many power and energy measuring instruments (meters and/or transducers) do you calibrate in a typical one-year period?:

Number of instruments calibrated in a typical year: _________

7. What is the approximate annual income for power and energy related measurements, tests, and calibrations? :

Annual income from measurements, tests, and calibrations: $ _________

8. What does it cost your Company to maintain and operate the meter, testing, and/or metrology (standards) laboratory? Incorporate your <u>total</u> budget for <u>all</u> electrical testing and calibrations. Consider your operating budget, capital equipment, and related costs. If operated at separate locations and budgets, please combine. If the response reflects any unusual circumstances, such as new facilities, fire or flood damage, laboratory consolidation, etc., adjust accordingly to typical normal year:

Total annual operating cost: $________

9. What portion of the overall laboratory costs given in response for question 8 above supports just power and energy (i.e., *watt, watthour, var,* and *varhour*) measurements, tests, and calibrations? Include costs related to repair and adjustments.

Portion for related power and energy effort: _______%

10. How much do you spend annually for the calibration of your electric power and energy standards by NIST or other sources of calibration?:

Annual cost of calibrating your power and energy standards: $_______

11. Does your laboratory derive the *watt, watthour, var,* or *varhour* on a regular basis from basic electrical standards (i.e., from voltage, current, impedance, phase angle, and time)?:

a. ☐ No, never has

b. ☐ Not now, but used to

c. ☐ No, but we would like to

d. ☐ Yes, still does

e. ☐ Yes, but we would like to quit

If you checked "c" or "d" above, can you briefly describe the benefits to your Company?:

____

____

____

If you answered "b" or "e" in response to question 11 above, what are the reasons for changing? Check all appropriate reasons. Indicate if a strong or weak reason. If "Other", please describe briefly.

Reason		
Strong	Weak	
f. ☐	☐	More cost effective to buy the service from NIST or other standards laboratory than to do it ourselves.
g. ☐	☐	Present measurement accuracies now make it technically difficult to derive the *watt, watthour, var,* and *varhour* ourselves with sufficient accuracy to meet our needs.
h. ☐	☐	Do not have the equipment, technical staff, management, budget, or training to derive and maintain our own power and energy standards to accuracies needed.
i. ☐	☐	Other (please describe briefly): ____________________

12. One way to evaluate the effectiveness and value of the NIST Calibration Service for electrical power and energy (namely, *watt, watthour, var,* and *varhour*) is to examine your operational and capital equipment costs considering IF this particular NIST Calibration Service were no longer available. (This is only a hypothetical exercise; NIST does not have plans to discontinue this Service.) What would you do? How would it impact your operations? What would it cost your Company?

Contrasted to **direct** NIST traceability by your Company, or from an independent standards laboratory which makes **direct** use of NIST Power and Energy Calibration Services (namely, *watt, watthour, var,* and *varhour*), instead consider a chain of traceability relying on the NIST Calibration Services for only voltage, current, impedance, phase angle, and time.

Measurement traceability to basic national standards could be achieved by use of one of two paths to NIST Calibration Services for the basic standards of voltage, current, impedance, phase angle, and time:

- **PATH ONE**: Your Company would be required to derive power and energy standards from the basic standards shown, or
- **PATH TWO**: An independent laboratory would derive the *watt, watthour, var,* or *varhour,* which in turn, would provide a calibration service to your Company.

Continued on following page.....

Which path would seem to best suit your operations? Remember that if you select to maintain traceability through "Path Two", NIST will also not offer the independent laboratory power and energy calibrations, but just the basic electrical calibrations for voltage, current, impedance, phase angle, and time.

a. ☐ Path One b. ☐ Path Two c. ☐ Other

If "other" was selected, can you briefly describe?: ______________________________

____

____

13. Using the path(s) selected above, and remembering the accuracy needs of your company, what would be your estimated **increased cost** for establishing and maintaining traceability in the absence of the present NIST Power and Energy Calibration Service? It might be useful to consider some of the following and how they might affect your operational costs:

The possible need for:

Added technical staff (consider also the technical level)
Increased managerial time and effort
Additional laboratory space and new capital equipment
Calibration and maintenance of new equipment
Training, travel
Additional shipping of standards, insurance
New record keeping and related paper work

Possible consequences might be:

Trade-offs and compromises in achieving needed accuracies
Possible loss of measurement accuracy
Increased cost of doing business

a. Estimated initial increased cost for establishing new calibration capability: $ ______

b. Estimated annual increased cost for establishing and maintaining traceability after initial costs have been absorbed:

$ ______

14. Can you provide examples that describe instances when NIST traceability, your calibrations and standards, or other measurements for power and energy have solved problems or saved money for your Company? (Please use examples related to measurements dealing with the quantities; *watt, watthour, var, varhour, demand, kVA, etc.*) Attach separately if more convenient.

a. Estimated dollar amount of savings: $ ______

These savings were a result of:

b. ☐ NIST traceability (direct or indirect)

c. ☐ Company calibrations and standards

***** THANK YOU FOR YOUR TIME AND EFFORT IN COMPLETING THIS QUESTIONNAIRE *****