

METERING AND CALIBRATION IN LOANSTAR BUILDINGS

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ABSTRACT

End-use metering in commercial buildings often requires installation of a large variety of transducers and data loggers. The metering installation group in the LoanSTAR monitoring program has the primary responsibility for the installation and maintenance of the metering hardware. This paper provides an overview of the responsibilities and first year experiences of the metering installation group of the LoanSTAR monitoring program. In addition, the calibration laboratory is also described.

Introduction

A major purpose of the LoanSTAR Energy Monitoring and Analysis Program is to verify the energy and dollars savings of the retrofits installed as a part of the LoanSTAR retrofit and loan demonstration program. To accomplish this purpose, a sample of buildings that include the different retrofits approved for the programs must be metered or sub-metered to determine the appropriate end-use energy consumption. Data collected from the building must be accurate and of sufficient detail to determine the energy savings and cost effectiveness of each retrofit.

The purpose of this paper is to describe the metering and equipment calibration portions of the LoanSTAR monitoring program. The metering program is first described, then the calibration laboratory. A summary of lessons learned in the first year is also provided.

Metering Program

The major ongoing functions of the metering group include: (1) determination of metering requirements, (2) subcontractor selection, (3) data acquisition system selection, and (4) installation and maintenance of systems. Each is discussed below.

Determination of Metering Levels

The monitoring program is intended to verify savings, ensure that retrofits operate properly and identify additional measures to reduce energy costs. Sufficient data must be collected to achieve these objectives, but monitoring and analysis expense must not undermine the cost-effectiveness of the retrofits that are a part of the LoanSTAR Program.

Evidence from Lawrence Berkeley Laboratory [1], Princeton [2,3], the Oak Ridge National Laboratory [4], the University of Colorado [5] and elsewhere shows the potential effectiveness of sub-metering large buildings with major retrofits. The savings achieved in smaller buildings do not

generally justify the expense of sub-metering. Such buildings will have whole-building energy consumption analyzed, sometimes with 15-minute or hourly demand data.

Four levels (Designated Levels 0,1,2, and 3) of systems have been developed for the monitoring program. These accommodate the necessary data requirements with the money available for monitoring retrofitted buildings. The levels also are compatible with different hardware available on the market. As the project progresses, the definitions of the levels and associated hardware requirements is expected to change. Table 1 presents guidelines for monitoring costs of the four levels. A fifth level will be explored in the second year of the project.

Level 0. Facility/whole building(s) utility data: A level 0 monitoring system is one that is already in place or where the agency collects the data to be forwarded to A&M. These data vary from monthly consumption data, based on utility bills, to weekly or daily data collected by utility meters. The data is useful for separating consumption into heating, cooling, water heating and other non-weather related consumption. A substantial portion of retrofits in the schools and local governments are expected to fall within this category.

Level 1. Whole-building and limited sub-metered hourly data: Ongoing work at Texas A&M, Princeton, and LBL shows that use of hourly data permits a more detailed analysis of end-use patterns and identification of major individual operating parameters within buildings than does the use of monthly or daily data; for example, whether lights or air conditioners are being turned off as scheduled. One to four channel data acquisition systems are utilized for this level of monitoring. Four channel data loggers can be utilized to obtain thermal energy (chilled and hot water), total electrical, and one other electrical end-use. Thus, this level is a viable option for buildings of intermediate size.

Level 2. Moderate sub-metered hourly data: This level has all the capabilities of the first two levels and also enables more detailed analysis for identifying the savings from specific retrofits and pinpointing building operational problems. The moderate sub-metered data acquisition systems will be simple four to twenty channel systems. Sub-metering in some small all-electric buildings can be accomplished with smaller systems to obtain adequate data at minimum cost.

Level 3. Detailed sub-metered hourly data: These systems typically include at least 20 channels of data. Given current costs for these systems, they are expected to be cost-effective only in large buildings with retrofits valued at more than \$500,000. Large buildings constitute about half of the expenditures expected in the first two years of the

Table 1 - Guidelines for first year monitoring costs

Monitoring Level	Retrofit Amount	Annual Energy Costs	Monitoring Costs
0 (Utility Data)	\$20k-\$50k	\$10k-\$30k	\$0
1 (1-4 channels)	\$50k-\$100k	\$30k-\$60k	\$3k
2 (4-20 channels)	\$100k-\$300k	\$60k-\$200k	\$10k
3 (20+ channels)	\$300k+	\$500k+	\$30k+

LoanSTAR program. These systems also are required in selected smaller installations (such as schools and local government buildings) to "calibrate" the simpler levels (i.e., daily or monthly manual watt-hour readings) of monitoring for different building types in Texas.

The feasibility of using an agency's existing EMCS to gather some or all of the required data is also being explored. Some vendors' EMCS allow for data collection, writing data to ASCII files, and remote interrogation. The EMCS would potentially offer a significant cost reduction over the installation of a stand alone data acquisition system. It also offers the potential of more data than would normally be gathered with a Level 3 system.

Data Acquisition System Subcontractors (DASS) Selection

Subcontractors are required to install and maintain data acquisition equipment in monitored buildings. The DASS prepare a metering installation plan for each monitored building, with the cooperation and approval of Texas A&M and the agency receiving the retrofit. Then the DASS selects hardware from the approved list and installs the system. The DASS also calibrate the system (including periodic recalibration) and provide maintenance as necessary to ensure that data collected during the monitoring period are usable.

DASS selection was based on guidelines in the Request for Qualifications (RFQ) that were sent to interested subcontractors. The selection committee consisted of several Texas A&M staff members and one staff member from the Governor's Energy Management Center (GEMC). Committee members were given copies of each respondent's RFQ and evaluated according to the following criteria:

1. general knowledge of data acquisition systems
2. knowledge of hardware and software
3. knowledge of calibration requirements
4. ability to staff project
5. quality of prior work
6. geographical location(s) in the state

Five engineering firms were qualified and four signed contracts to work as DASS on the project. These included:

1. National Center for Appropriate Technology (Ncat), Butte, MT. Ncat is a non-profit organization and has been involved in numerous building energy use installations and studies. They have been assigned the majority of the sites during the first year.
2. McEver Systems Engineering Incorporated (MSE), Houston, TX. MSE completed the Capitol Complex in Austin. MSE has dropped out of the program because the president of MSE took an executive position with a former employer.
3. ADM Associates, Sacramento, CA. ADM has been assigned one large installation.
4. Architectural Energy Corporation (AEC), Boulder, CO. AEC has been assigned two installations.

All four DASS were assigned sites the first year so they could be evaluated for continued participation in the program. The continued participation of any of the DASS in the program depended on the quality, cost, and timeliness of their monitoring installations.

Data Acquisition Systems Selection

Data acquisition systems included both the data-logging hardware and transducers which measure electrical power, temperature, pressure, etc. The selection process for these systems is continuing. As new hardware is qualified, it is included on an approved hardware list from which the DASS may make purchases.

A list of data logging equipment being evaluated for each level of monitoring is shown in Table 2. The equipment must have an open communications protocol to be incorporated into the LoanSTAR program. Each system evaluation included compatibility with data transmission protocols and any other equipment it must interface with before being listed. Only the synergistic system was approved for the first year.

Quantity discounts were negotiated with some of these manufacturers which reduced the purchase price of data

**Table 2 - Data logging hardware
being evaluated**

Level	Manufacturer
1	Landis and Gyr/Synergistics Controls/ RusTrak/Sangamo/Process Systems
2	Campbell/Synergistics Controls
3	Synergistics Controls

loggers and some transducers by 10% to 25% below single-purchase prices.

Estimating the savings due to a retrofit requires accurate estimates of end-use energy in many of the buildings. End-use measurements require a variety of transducers. Listed below are the transducers that have been included in some of the data acquisition systems already installed.

- | | |
|------------------------|-------------------------|
| 1. electrical sensors | 4. airflow meters |
| current transducers | hot wire |
| wattmeters | pitot-static |
| watt-HR meters | turbine |
| 2. temperature sensors | 5. waterflow meters |
| RTD | insertion |
| thermocouple | venturi |
| IC | 6. pressure transducers |
| 3. humidity sensors | differential |
| relative humidity | total |
| dew point | 7. anemometers |
| | 8. Btu meters |
| | 9. pyranometers |

Installation and Maintenance of Systems

Once an agency has applied for a loan to the GEMC, the buildings that are a part of the loan must be evaluated for metering. The installation of a monitoring system typically progresses with the following steps:

Development of a preliminary monitoring and analysis plan (PREMAP)

Once the agency loan is approved by the GEMC, a site visit to the building(s) is conducted by a project engineer to determine the relevant information for monitoring the building.

The second step in the PREMAP process for a building is an initial visit to the site by the DASS. For the larger monitoring sites, an engineer from Texas A&M accompanies the DASS to the site to assist in coordination with the agency and resolve any questions regarding the monitoring effort for the site.

The DASS develops a PREMAP from this initial site visit. The PREMAP includes options for hardware (specified by brand name), communications recommendations, major energy using equipment (air handlers, chillers, etc.) locations, detailed drawings of the proposed monitoring

installations, data to be provided, data format, and estimates of hardware and installation costs.

Development of a site monitoring and analysis plan (SITEMAP)

The PREMAP is submitted by the DASS. It is reviewed for completeness in meeting budgetary constraints and specific metering requirements. A SITEMAP is then developed that contains the final recommendations for the type of monitoring system to install, locations of instrumentation, costs, etc. The agency receiving the monitoring system must concur with the SITEMAP to ensure that the proposed installation does not interfere with their desires for the system. The agency's concurrence also is important because a portion of the money for the monitoring system may be paid by the agency out of its retrofit loan. The SITEMAP is then submitted to the GEMC for final approval.

System Verification:

Data verification is performed immediately after the monitoring equipment is installed. The data is compared with past utility data, auditor estimates of consumption and any other information available to verify that the data acquisition system and sensors are providing reasonable values. This is followed by checks of most sensor outputs. Such checks are performed periodically for data quality assurance. The system verification occurs within the first sixty days after the system is installed. The DASS is required to correct any equipment problems at the site during this period as part of the installation contract.

Maintenance of Monitoring System:

During the first 60 days after the installation of the system, the DASS is wholly responsible for any maintenance of the system. After 60 days, maintenance on the site is handled by personnel at Texas A&M or the DASS, depending on the type of maintenance required. Unscheduled emergency repair is handled on a "case-by-case" basis with the DASS. Calibration of the transducers is handled with a portable calibration unit.

First Year Installation:

Table 3 provides a list of the agencies where monitoring systems have been started during the first year of the program. Over 80 buildings and 400 points are a part of the monitoring program during the first year.

Table 3 - Monitored installations started during the first year of the program.

Agency Name	Location	Projected Savings*	Cost of Monitoring*	# of Bldgs	# of Points
Texas A&M	College Station	\$411.1	\$42.0	1	45
Texas Dept. of Health	Austin	\$60.6	\$22.4	5	7
MHMR - El Paso	El Paso	\$17.1	\$14.2	1	12
MHMR - Austin Hospital	Austin	\$336.5	\$11.0	1	5
MHMR - Austin School	Austin	\$102.9	\$20.0	1	3
MHMR - Terrel	Terrell	\$343.7	\$51.7	6	16
U.T. Arlington	Arlington	\$352.2	\$56.2	6	39
Texas A&M, Galveston	Galveston	\$26.6	\$27.0	9	8
U.T. Austin	Austin	\$1493.5	\$180.8	16	156
U.T. Medical Branch	Galveston	\$1100.8	\$87.3	8	26
U.T. Health Science Center	Dallas	\$283.5	\$30.9	4	16
U.T. Dallas	Dallas	\$118.4	\$34.3	6	10
T.T. Health Science Center	Lubbock	\$333.3	\$15.0	1	15
U.T. Health Science Center	Houston	\$218.3	\$32.7	2	12
U.T. Health Science Center	San Antonio	\$110.9	\$15.0	2	8
Univ. of North Texas	Denton	\$65.5	\$7.0	1	7
Capitol Complex	Austin	\$500.0	\$130.4	11	56
TOTALS:		\$5074.8	\$779.9	81	441

* Amounts are in thousands of dollars.

Calibration Laboratory

The accuracy of the installed sensors is key to a successful energy monitoring project. Data obtained for this project must be accurate to maintain confidence and reliability. To assure that accurate data are collected, a National Institute of Standards and Technology (NIST) traceable calibration laboratory has been established at Texas A&M University.

The objectives of the calibration laboratory are to provide:

1. Testing of sensors to verify their compatibility with selected monitoring systems,
2. Troubleshooting of faulty sensors found in the field to check the difference between bench tests and field sensor installations,
3. Verifying of portable instrumentation which can be used for field testing and validation,
4. Bench-testing and pre-qualifying of proposed hardware systems prior to installation in the field, and
5. Developing field calibration techniques and error analysis to verify insitu systems.

The philosophy behind establishing the calibration laboratory is to be able to verify both sensor accuracy and compatibility with the monitoring systems before field installation. In too many projects, the field installation is the first check of system compatibility. Field installation problems likely will arise with faulty sensors or a faulty class of sensor. Since the DASS are required to maintain and verify periodic calibration of their systems in the field, the ESL calibration facility can be used to determine sensor

problems and also resolve potential conflicts about incorrect sensor readings.

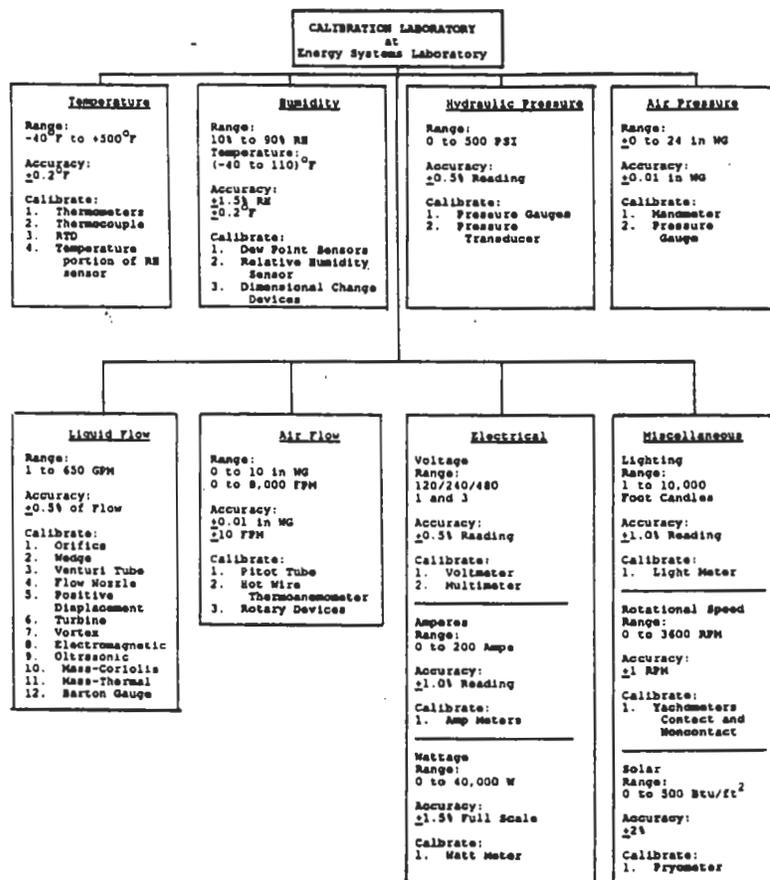
Calibrated portable instrumentation is being developed for spot checks on installed hardware. The DASS is responsible for installing the system and certifying proper operation. The unit also can be used for trouble-shooting older installations when problems arise.

The accuracy of sensor calibration is the key to the whole monitoring project. Data obtained from buildings has to be accurate to maintain confidence in the project. To verify the accuracy of sensors, NIST-traceable calibration is absolutely necessary. NIST-traceable services are available to potential hardware for all the common quantities (i.e., temperature, velocity, flow, rpm, etc.) that are encountered in this program. Field installed sensors and systems are rechecked periodically to verify their continued calibration.

Operational guidelines are being developed for sensors and hardware. The DASS is required to follow the manufacturer's installation instructions for sensor installation, calibration and maintenance procedures.

The calibration facility includes the capability to measure electrical energy, power factor, electrical demand, temperature, air and liquid flow rates, humidity, pressure, solar radiation, light levels, air velocity and rpm. Services available from local utilities are used for calibration of electrical watt-hour meters and natural gas meters. The calibration capability being developed is shown in Figure 1. Some statement of status is appropriate.

Figure 1. LoanSTAR Calibration Laboratory. This figure describes the calibration facilities being developed for checking the accuracy of instruments and sensors used in the LoanSTAR Program.



Lessons Learned to Date

The first year's experience of undertaking a large-scale energy monitoring project has taught us many lessons. Major issues and lessons learned include:

- (1) Most buildings do not have current as-built drawings. The existing location of equipment that will be monitored, electrical wiring, piping, etc, must be obtained from site inspections and having access to the "right" agency personnel.
- (2) The use of existing electric utility meters, gas meters, and certain thermal meters is not always feasible. Some existing equipment has been found to be inoperative, improperly sized, or out of calibration. Often it is less expensive to install new equipment than to trace an existing meter manufacturer's calibration data, modify the transducers, etc.

- (3) Large thermal flows can be expected at most university campuses that have centralized utility distribution systems. Monitoring thermal flows is expensive, and is compounded by the fact that few installers have significant experience with such metering. Costs for similar equipment from different manufacturers can vary dramatically.
- (4) Buildings are not well-suited for end-use electricity measurements. Panels for the same end-use can be located hundreds of feet or many stories away from each other. Power measurements across multiple panels can increase costs dramatically. Buildings often have multiple electrical feeds or feed additional buildings.
- (5) Asbestos is found in many chilled and hot water piping installed before 1970. Installation of thermal metering requires asbestos abatement. The cost to remove the

- asbestos may be too high to justify the thermal metering.
- (6) Timely installation of equipment requires an intensive coordination effort during the PREMAP phase of a project. Several early installations encountered lengthy time delays because of coordination between different groups within the same agency, problems in establishing who had authority to make decisions, etc.
 - (7) We see a definite need to develop better procedures for calibrating in-site electrical and large thermal measurements.

Summary

The first year has been a learning experience. We have had to develop the procedures that would allow for smoother installation of metering systems. Installation of the metering systems is expensive. However, we have been able to reduce costs in our metering installations through price negotiations of equipment, careful planning of installations, and exhaustive comparison shopping of equipment. Many of the changes in our approach to installing metering have been incorporated in the new sites for the second year. As new sites are brought on-line, we anticipate learning more about the problems associated with the day-to-day operations and maintenance of the monitoring systems.

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