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Mobile Energy Laboratory Procedures

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Preface

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, facility assessment, and use of cost-sharing procurement mechanisms. Technology development focuses upon the tools, software, and procedures used to identify and evaluate energy efficiency technologies and improvements. For facility assessment, FEMP provides metering equipment and trained analysts to federal agencies exhibiting a commitment to improve energy use efficiency. To assist in procurement of energy efficiency measures, FEMP helps federal agencies devise and implement performance contracting and utility demand-side management strategies.

Pacific Northwest Laboratory (PNL)^(a) supports the FEMP mission of energy systems modernization. Under this charter, the Laboratory and its contractors work with federal facility energy managers to assess and implement energy efficiency improvements at federal facilities nationwide.

The Mobile Energy Laboratory (MEL) Procedures establish guidelines for measuring and analyzing the efficiency of on-site energy conversion, distribution, and end-use application on federal facilities.

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Executive Summary

Pacific Northwest Laboratory (PNL) has been tasked to plan and implement a framework for measuring and analyzing the efficiency of on-site energy conversion, distribution, and end-use application on federal facilities as part of its overall technical support to the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP). The Mobile Energy Laboratory (MEL) Procedures establish guidelines for specific activities performed by PNL staff.

PNL provided sophisticated energy monitoring, auditing, and analysis equipment for on-site evaluation of energy use efficiency. Specially trained engineers and technicians were provided to conduct tests in a safe and efficient manner with the assistance of host facility staff and contractors. Reports were produced to describe test procedures, results, and suggested courses of action. These reports may be used to justify changes in operating procedures, maintenance efforts, system designs, or energy-using equipment. The MEL capabilities can subsequently be used to assess the results of energy conservation projects.

These procedures recognize the need for centralized MEL administration, test procedure development, operator training, and technical oversight. This need is evidenced by increasing requests for MEL use and the economies available by having trained, full-time MEL operators and near continuous MEL operation. DOE will assign new equipment and upgrade existing equipment as new capabilities are developed. The equipment and trained technicians will be made available to federal agencies that provide funding for the direct costs associated with MEL use.

Acknowledgments

The authors would like to thank the U.S. Army Corp of Engineers and U.S. Army Forces Command (FORSCOM) personnel who assisted in reviewing the numerous draft Mobile Energy Laboratory (MEL) Procedures over the past several years. We wish to specifically acknowledge our sponsor, Adrian Gillespie of FORSCOM, for his progressive attitude toward energy efficiency within the U.S. Army and for recognizing the need for standardized field monitoring procedures to develop a sound understanding of energy use at U.S. Army bases. The authors would also like to recognize the late James Vasiloff of FORSCOM who initiated this effort and was instrumental in getting it started.

Appreciation is also extended to PNL staff whose contributions supported this effort until its completion: Eric Richman for his thorough review of each of the procedures, Cathy Anderson for final editing, and Graham Parker for his encouragement by keeping our team focused on the primary objective. Without their dedication, the MEL Procedures would not have been possible.

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Acroynyms and Abbreviations

ADPE	automatic data processing equipment
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BSEE	boiler system efficiency evaluations
CU	coefficient of utilization
DOE	U.S. Department of Energy
ECM	energy conservation measures
EDS	electrical distribution system
EEUM	electrical end-use metering
FD	forced draft
FDAS	Field Data Acquisition System
FORSCOM	U.S. Army Forces Command
FOV	field of view
HO	Hanford Operations
HVAC	heating, ventilating, and air conditioning
ID	induced draft
IES	Illuminating Engineering Society of North America
IFOV	instantaneous field of view
IR	infrared
ISS	initial site survey
kVA	kilovoltampere
LIPD	lighting input power density
LN ₂	liquid nitrogen
LOS	line of sight
MAP	MEL Application Plan
MEL	Mobile Energy Laboratory
MP	measurement plan
MRTD	minimum resolvable temperature difference
NA	not applicable
NEC	National Electric Code
NEESA	Naval Energy and Environmental Support Activity
OSB	Operations and Services Building
PNL	Pacific Northwest Laboratory
SCS	site characteristics survey
SDS	steam distribution system
SIC	Standard Industrial Classification
TI	temperature index
VAV	variable air volume
VCR	video cassette recorder
WHC	Westinghouse Hanford Company

Introduction

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, facility assessment, and use of cost-sharing procurement mechanisms.

Pacific Northwest Laboratory (PNL) has been tasked by DOE to plan and implement a framework for measuring and analyzing the efficiency of on-site energy conversion, distribution, and end-use application on federal facilities as part of its overall technical support to DOE. The Mobile Energy Laboratory (MEL) Procedures establish guidelines for specific activities performed by PNL staff. Specific test procedures were developed for common investigations. Specially trained engineers and technicians were provided to conduct tests in a safe and efficient manner with the assistance of host facility staff and contractors. Reports were produced to describe test procedures, results, and suggested courses of action. These reports may be used to justify changes in operating procedures, maintenance efforts, system designs, or energy-using equipment. MEL capabilities can subsequently be used to assess the results of energy conservation projects.

These procedures recognize the need for centralized MEL administration, test procedure development, operator training, and technical oversight. This need is evidenced by increasing requests for MEL use and the economics available by having trained, full-time MEL operators and near continuous MEL operation. DOE will assign new equipment and upgrade existing equipment as new capabilities are developed. The equipment and trained technicians will be made available to federal agencies that provide funding for the direct costs associated with MEL use.

Procedure 1.0 provides test plan preparation guidelines for energy efficiency project identification and evaluation at federal facilities. Guidelines for transfer and readiness preparation of a MEL, and the equipment assigned to the MEL, are provided in Procedure 2.0. Procedure 3.0 provides guidelines for the inventory, calibration/repair, and accountability of the equipment assigned to the MELs to ensure that MEL equipment is in optimum operating condition at all times. Procedure 4.0 is the Safety Operation Plan designed for use with all MEL work performed at PNL, or federal and other installations. Basic guidelines for conducting electrical end-use metering within targeted buildings is provided in Procedure 5.0. Procedure 6.0 defines a testing methodology to be used in evaluating illuminance levels in facilities. Procedure 7.0 defines guidelines for the examination, problem identification, and evaluation of a facility steam or hot water distribution system. Procedure 8.0 is a standard reference document to be used by MEL field specialists while performing an electrical distribution system evaluation (EDS), and is intended to serve as a basic guideline for all activities that are required to complete an EDS evaluation. Basic guidelines for conducting boiler system efficiency evaluations are provided in Procedure 9.0. Procedure 10.0 describes a testing methodology for using infrared thermography instrumentation in the identification and evaluation of apparent temperature anomalies potentially associated with anomalous heat transfer.

Mobile Energy Laboratory

Procedure 1.0

MEL Application Plan Development Guide

1.0 MEL Application Plan Development Guide

1.1 Introduction

This procedure provides test plan preparation guidelines for energy efficiency project identification and evaluation at federal facilities. This procedure is intended to serve as the guiding document from the time a request for services of a Mobile Energy Laboratory (MEL) is received until the completion of the MEL Application Plan (MAP) for the site. A MAP involves the initial screening activities performed when candidate facilities apply for MEL services.

1.2 Scope

Operational procedures are provided as the basis for effectively screening candidate sites and completing a MAP. Data collection forms are provided to ensure that appropriate information is collected for the initial screening of candidate sites for MEL services. These forms may serve as the primary data collection and filing mechanism for MAP development. Procedures are provided to initiate a site into the process, make an initial site visit for screening purposes, develop specific test plans, and for MAP preparation. The forms are provided in hard copy and electronic format. They may be completed in the most convenient manner, but hard copies should always be placed in the site files.

1.3 Summary of Procedure

The flowchart shown in Figure 1.1 is a simplified expression of the flow of activities necessary to complete an initial site screening. More detailed explanations of each step's elements are provided in this procedure. For some facilities, it may be necessary to loop back to previous steps in the procedure as compounding factors are uncovered during the development of the MAP. The flowchart is a basic framework; and, therefore, allows for significant modifications to conform with each individual site's circumstances. Multiple sites can proceed through the process in parallel, and for some sites, a MAP may never be completed.

1.4 Significance and Use

The preparation of a MAP is specifically designed as a precursor to a MEL application for testing/evaluations of energy conservation opportunities. Elements of the procedure may be applicable to a generalized examination of any facility for any energy-efficiency assessment. Users of the procedure should use their discretion to determine which elements of the procedure are most applicable to their application.

1.5 Apparatus

MAP preparation is dominated by the collection of descriptive and other preparatory information, so little special equipment is required. The site team shall be provided with the MEL testing catalog and copies of the initial inspection forms for the specific efficiency tests that may be

Figure 1.1. Simplified Flowchart of Required Activities for Completing the Initial Site Visit

required. A set of simple hand tools and electrical measurement multimeters and flashlights should be the only required tools. For ease in report preparation, record keeping, and utility billing analysis, a portable computer is required. Some sites may require the collection of supplemental data that requires appropriate data collection equipment, such as a Dranetz Model TM-110300, Series 808 electric power demand analyzer, Dranetz Technologies, Inc., Edison, New Jersey.^(a)

1.6 Hazards

On-site activities present a potential for personal injury to personnel. Prudent safety precautions shall be taken at all times. Obtain and use (wear) whatever safety equipment is required, such as seat belts, safety glasses, hard hats, and hearing protectors.

1.7 Procedure

This section describes the requirements for each step to complete a MAP. Usually, a complete process is outlined that includes the necessary data collection forms and procedures.

1.7.1 Initial Request for Facility Evaluation

A request for MEL services at each candidate facility is received at Pacific Northwest Laboratory (PNL). The first step in the MAP process provides a mechanism to accept the facility, collect initial information, and confirm its accuracy. A Service Request form (see Appendix A) shall be completed by the PNL project manager or designated individual, using information provided in the transmittal document from the requesting organization. The transmittal document and the service request form are the beginning of the site file. Depending on the source of the initiating document, various methods of confirmation may be required. At a minimum, the sponsor must be informed of the acceptance for a facility evaluation, and new sites must be outlined in the periodic project reports.

1.7.2 Contractual Requirements

To ensure that PNL and MEL related activities are reimbursed, and to protect participating parties, a contractual agreement between PNL and the requesting agency shall be completed. For requests received under the auspices of the U.S. Army Forces Command (FORSCOM), those arrangements are in place and the only required document is a letter confirming receipt of the request and a recognition that it falls within the allowed budget. For facilities outside the FORSCOM umbrella, specific contractual agreements must be established. Project staff shall work with PNL contractual and financial staff to prepare documents acceptable to their counterparts in the requesting organization. As MAPs are developed, the contractual documents must be updated with more accurate cost and schedule estimates.

(a) References to specific manufacturers and models are not to be construed as an endorsement as compared to equivalent instrumentation available from other manufacturers.

1.7.3 Site Telephone Contact

Based on information provided in the transmittal document, the site contact is telephoned and the information in the Service Request form is confirmed or modified as necessary. Each item on the form must be explicitly discussed with the site contact; do not take anything for granted - confirm everything. An Initial Telephone Data form (see Appendix B) shall be completed during a telephone conversation with the site contact and added to the site file. These initial activities confirm the basic information about the facility, contacts, and expected activities. Arrangements for the initial site inspection visit shall be completed and requests made for copies of utility bills and engineering data (plans).

1.7.4 On-Site Briefing

Initial site activities should be devoted to meeting a range of individuals, which should include senior level management personnel and operational personnel who will be the primary contacts. Briefings by PNL staff about the capabilities of the MEL and the expected activities during MAP preparation should be included, as well as a preliminary projection of possible future activities. The briefing shall reflect realistic budgets and schedules. It is always better to deliver more than promised. Delivering less than expected will quickly lead to problems. Be complete, honest, and forthright. Obtain commitments from senior staff for support of all activities. If possible, obtain a statement in writing from senior staff to be used to convince noncooperative personnel that PNL deserves their support. Identify the site contact that can assist in information collection and be involved in a site tour. During these meetings and discussions, a copy of the site file should always be available for reference.

1.7.5 Collecting Site Information

Significant information about the site must be collected for effective MAP preparation. The Site Information form (see Appendix C) provides a mechanism to collect that information. The PNL representative should work with the site contact to completely fill in the required information. In Appendix C, Page C.1 is general descriptive information about the facility. Page C.2 explores energy-efficiency program experiences and general expectations/plans. Page C.3 explores possible site restrictions and spells out the specific MEL testing expectations. Page C.4 documents the suitability of utility and engineering data available at the site. A Specific Test Identification/Preliminary Evaluation form (see Appendix D) shall be completed for each specific test identified at this stage of the screening exercise. Parts of the form are completed during and after the site tour, but the test must be fully described at this stage of MAP preparation. As a central collection of all site contact information, an Important Contact List form (see Appendix E) shall also be completed during the meeting with the site contact. This list shall continue to be developed and enhanced as experiences at a specific site continue. At this time, collect the basic contact list information with special emphasis on security, safety, and emergency contacts. All forms are added to the site file at the conclusion of the meeting, and a site tour is scheduled.

1.7.6 Site Tour

The site tour shall include a general overview road tour of the facility. Sensitive and excluded areas should be avoided unless they are to be included in the MAP. Ensure that appropriate clearance/security arrangements are in place. Never attempt to coerce entry into closed buildings or areas. Unauthorized access may lead to problems for PNL and site personnel. The location of each identified test should be visited and a preliminary evaluation completed. The nature of these evaluations depends on the nature of the specified tests. Complete the additional information on Appendix D. Make special note of those locations that require, or may benefit from, the collection of supplemental data. The PNL representative must maintain an open mind and a high degree of sensitivity to other potential MEL applications. Watch for, record, and discuss any opportunities for improving energy efficiency. Note broken windows, leaking steam traps, steam plumes coming from drains, and fully lit empty buildings.

1.7.7 Collecting Supplemental Information

Specific tests that are identified often first require the collection of special and/or unique information. For example, end-use electric metering requires the completion of the Initial Site Inspection before it is possible to fully ascertain the feasibility and cost of the test procedure. Each identified test that requires these initial steps should have them completed prior to leaving the site. Exceptions exist that preclude the completion of these specific initial tests, but every effort should be made to fully complete as many as is feasible. There are other tests/issues that may be clarified by the collection of specific information. An example is the installation of a Dranetz meter at a building to further clarify its specific energy profile for justification of more detailed instrumentation. This type of data shall be decided on for each specific issue. Utility billing information should be processed through the PNL developed evaluation routine that helps identify and separate temperature/seasonal dependent consumption from operational variability. This routine also provides a programmatic growth estimate and its impact on facility energy use, which helps to focus on the types of energy problems at the facility and improve the cost effectiveness of the testing program.

1.7.8 Application Plan

The primary product of the screening activity is a complete and detailed MAP, which provides the projected elements of the MEL testing activities, the expected schedule, and a complete cost estimate in a concise form. The MAP document shall include a summary that combines all of the projected tests into a single grouping. In addition, specific detail shall be provided for each of the possible tests. High-cost options include strong economic and engineering justifications. The MAP shall also include completed copies of the Specific Test Identification/Preliminary Evaluation for each identified test, which documents the critical elements and reasons for the tests and provides a cost estimate and space for approval of the appropriateness of the activities. Additional required detail shall also be prepared for each identified test. The Specific Test Identification/Preliminary Evaluation form includes the minimum required data, but may not be sufficient to fully understand the reasons and benefits of the outlined test. High-priority MAPs may be handled in an expedited manner using the project's electronic mail facility.

1.8 Annexes and Appendixes

1.8.1 Annexes

FORSCOM	U.S. Army Forces Command
MAP	MEL Application Plan
MEL	Mobile Energy Laboratory
PNL	Pacific Northwest Laboratory

1.8.2 Appendixes

Appendix A contains the Service Request form, which is used to collect site information during the initial request for a facility evaluation.

Appendix B contains the Initial Telephone Data form, which is used to confirm site information by telephone.

Appendix C contains the Site Information form, which provides a mechanism for collecting significant site information.

Appendix D contains the Specific Test Identification/Preliminary Evaluation form that is completed for each specific identified test.

Appendix E contains the Important Contact List form, which is completed during the site visit to serve as a capital collection of all site contact information.

1.9 Personnel Support

Site screening requires individuals who are familiar with the entire range of MEL testing capabilities and an understanding of energy issues as they relate to federal sites and facilities. For small facilities, a single individual is sufficient to conduct the site screening, and for larger facilities, a team of two or three individuals is required to complete the survey and data collection efforts. The team should be the same team that will be involved in the actual testing activities so that an ongoing relationship can be established with site personnel. One of the most important elements of MAP preparation is the establishment of working relationships with site personnel, ranging from the site contact that is ultimately responsible for the energy issue to the operators of key pieces of equipment or buildings. It is essential that one or two site contacts (energy manager or equivalent) be identified as the key point for project interface. These site contacts must have adequate authority to enable the team to effectively accomplish its mission, as well as sufficient knowledge of the site and its energy issues to direct the team to the appropriate source of required information. Numerous other individuals representing trades, engineering, and utilities shall be involved during the site screening visit.

1.10 Testing Schedule

MAP development requires approximately 1 week at a typical facility. Preparatory actions require approximately 2 days, but may be spread over a relatively long period of time depending on the schedules of the PNL team and site contacts. It is desirable to complete the screening actions within 3 months of receipt of the initial request for services.

1.11 Delivery Requirements

The site screening activity product shall be a detailed MAP that includes descriptions of specific tests to be performed. The MAP is a relatively brief document that includes copies of the completed forms, as well as a brief written report with recommended actions. A complete summary budget estimate shall also be provided. Sometimes, the results of the screening exercise recommend no action or action much different than originally planned. Therefore, the summary report must be complete and concise.

Appendix A

Service Request

Initial _____
Corrected _____

Date Received: _____ Date Site Contacted: _____

Date: _____ Completed by: _____

Site ID: _____

Location: _____

Site Contact: _____ Telephone: _____

Alternate: _____ Telephone: _____

Initial Testing Requirement: _____

Federal Organization: _____

Funds Source for Testing: _____

Schedule Expectations: _____

Schedule Limitations: _____

Comments: _____

Appendix B

Initial Telephone Data

Date: _____ Completed by: _____

Site ID: _____

Site Contact: _____ Telephone: _____

Alternate: _____ Telephone: _____

Working Contact: _____ Telephone: _____

Preliminary Schedule for Site Screening Visit: _____

Fuels	Bills Available	Copies	Requested	Comments
Electricity	_____	_____	_____	_____
Natural Gas	_____	_____	_____	_____
Oil	_____	_____	_____	_____
Coal	_____	_____	_____	_____
Bottle Gas	_____	_____	_____	_____
Other	_____	_____	_____	_____

Central Billing Data Archive:

Billing Custodian: _____

Engineering Data (Plans)

	Available	Requested	Comments
Site Layout	_____	_____	_____
Electrical Distribution	_____	_____	_____
Steam Distribution	_____	_____	_____
Buildings	_____	_____	_____
Mechanical/Electrical	_____	_____	_____
Other	_____	_____	_____

Central Archive:

Custodian: _____

MEL Location Available: _____ Yes _____ No

Appendix C

Site Information (General Descriptive Facility Information)

Date: _____ Completed by: _____

Site ID: _____

Site Contact: _____ Telephone: _____

Size of Facility: _____

Function of Facility: _____

Number of Buildings: _____

Total Square Footage of Conditioned Space: _____

Major Process Loads: _____

Schedule of Operations: _____

Average Number of Personnel: _____

Maximum Number of Personnel: _____ Minimum Number of Personnel: _____

Servicing Utilities	_____
Electricity	_____
Natural Gas	_____
Oil	_____
Steam	_____
Other	_____

Rate Schedules: _____

What Services Are Supplied to Other Facilities: _____

Site Information (Energy-Efficiency Program Experiences and Expectations/Plans)

Date: _____ Completed by: _____

Site ID: _____

Weather Data Collected on Site: _____

Explain Any Previous Submetering: _____

Experience with Energy Projects: (use extra sheets as required)

Recent: _____

Planned Within Next Six Months: _____

Would Like to Investigate: _____

Previous Studies/Audits: _____

Phone Lines Available: _____

Suitable MEL Location Available: _____

Site Information (Site Restrictions)

Date: _____ Completed by: _____

Site ID: _____

Access Restrictions: _____

Classified Activities: _____

Special Requirements: _____

Expected Testing Requirements: _____

Site Information (Available Utility and Engineering Data)

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

Fuels	Bills	Obtained	Sufficient	Comments
Electricity	_____	_____	_____	_____
Natural Gas	_____	_____	_____	_____
Oil	_____	_____	_____	_____
Coal	_____	_____	_____	_____
Bottle Gas	_____	_____	_____	_____
Other	_____	_____	_____	_____

Central Billing Data Archive: _____

Billing Custodian: _____

Engineering Data (Plans)
Obtained Sufficient Comments

Site Layout	_____
Electrical Distribution	_____
Steam Distribution	_____
Buildings	_____
Mechanical/Electrical	_____
Other	_____

Central Archive: _____

Custodian: _____

Comments: _____

Appendix D

Specific Test Identification/Preliminary Evaluation

Date: _____ Completed by: _____

Site ID: _____ Test No. _____

Test Objective: _____

Test Description: _____

Schedule Requirements: _____

Cost Estimate:

PNL personnel, equipment, and reporting: \$ _____

DEH support: man-hours _____

Approvals:

MEL Tech Coordinator Date

MEL Project Manager Date

Site Representative Date

FORSCOM Date

Cost Summary

Date: _____ Completed by: _____

Site ID: _____ Test No. _____

Manpower: Assume weeks for data collection

Activity	DEH Support (man-hours)	PNL Staff		Manpower cost
		Technician (man-hours)	Engineer (man-hours)	
Equip. Installation				\$
Equip. Removal				\$
Test Operation (m-h/wk)				\$
Analysis/Reporting				\$

Supplies: \$ _____

Equipment Usage/Calibration: \$ _____

Travel/Living: \$ _____

Total Cost Estimate:

PNL personnel, equipment, and reporting: \$ _____

DEH support: man-hours _____

Appendix E

Important Contact List

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

PERSON	PHONE
Formal Site Contact:	_____
Site Energy Manager:	_____
Electrician:	_____
Pipe Fitter:	_____
Engineering:	_____
Telephone:	_____
Electric Utility:	_____
Motor Pool:	_____
Lodging:	_____
Security:	_____
Safety:	_____
Emergency:	_____
Boiler Plants:	_____

Building: _____

MEL Phone: _____

Mobile Energy Laboratory

Procedure 2.0

Property Management Guidelines

2.0 Property Management Guidelines

2.1 Introduction

Guidelines for transfer and readiness preparation of a Mobile Energy Laboratory (MEL), and the equipment assigned to the MEL, are provided in this procedure. These guidelines serve as a guiding document while the MEL is on assignment and between assignments.

2.2 Scope

Common operational procedures are provided as a basis for effectively transferring the MELs and contained equipment to Pacific Northwest Laboratory (PNL) and preparing this property for assignments. Inventory and property control forms and procedures are provided to ensure that appropriate information is obtained for efficient transition of the MEL property to PNL. Guidelines are also provided for initial maintenance of the MELs and testing equipment.

2.3 Summary of Procedure

The flowchart shown in Figure 2.1 is a simplified expression of the flow of activities necessary to prepare the MELs and contained equipment for field readiness.

Figure 2.1. Flowchart of Activities to Prepare the MELs and Equipment for Field Readiness

2.4 Significance and Use

This procedure is a guideline for effectively processing the necessary documentation to prepare the MELs and contained equipment for assignment.

2.5 Hazards

Transportation of the MELs and testing equipment requires activities that subject personnel to risk of personal injury. Prudent safety precautions are to be taken at all times when moving the MELs or checking the equipment. Seat belts shall be worn at all times when a MEL is in transit. When working on MEL equipment, appropriate safety equipment shall be obtained and used (worn), such as safety glasses, hard hats, and hearing protectors.

2.6 Procedure

The required steps for completing the transfer and readiness of the MELs and contained equipment are described below. PNL property control forms shall be completed and copies provided in the site files.

2.6.1 Property Transfer to PNL

When a property transfer of a MEL to PNL is initiated, a Special Equipment Request form (see Appendix A), an Assignment and Justification Questionnaire (see Appendix B), and a copy of the letter transferring the MEL to PNL from the previous owner is sent to:

Pacific Northwest Laboratory
Facilities Specialist
Facilities Planning and Administration
PO Box 999, P7-05
Richland, Washington 99352

The property transfer is then forwarded for approval by PNL to:

U.S. Department of Energy (DOE)
Richland Operations Office
Operations Officer
Research and Development Division
P.O. Box 550, A5-90
Richland, Washington 99352

An Equipment Tracking Form shall be completed for all transferred equipment (see Appendix C).

2.6.2 Credit Card Assignment

A letter requesting that credit cards be assigned to a MEL are sent to:

Westinghouse Hanford Company
Manager, Bus and Transportation Office
P.O. Box 1970
Richland, WA 99352

2.6.3 Tagging Property with Hanford Operations Number

After the special equipment request has been approved, PNL shall notify Westinghouse Hanford Company (WHC), who assigns the MEL a Hanford Operations (HO) number to be tagged on the property. This number must be assigned before a Class A maintenance inspection can be scheduled with the WHC Motor Pool.

2.6.4 Initial Maintenance Inspection

A Class A maintenance inspection shall be performed on each MEL by the WHC Motor Pool. Contact the WHC Heavy Equipment Manager to schedule this inspection, who will have a WHC bus driver move the MEL to the garage and schedule the maintenance. A list of known required repairs must accompany the MEL.

2.6.5 Routine Maintenance

Routine maintenance shall be performed on the MELs by the WHC Motor Pool according to the maintenance contract. This contract is renewed annually.

2.6.6 Off-Site Maintenance

When a MEL is off site and requires maintenance, call the PNL Operations and Services Building (OSB) Receptionist and request a telephone emergency purchase requisition. The required information may be given over the phone and approvals may be made for a qualified mechanic to perform the maintenance.

2.6.7 Equipment Physical Inventory

A physical inventory following the MEL equipment inventory procedure shall be performed upon possession of a MEL and before it is moved off site for assignment. Upon completion of each off-site assignment, and at a minimum of every 6 months, an equipment physical inventory shall be performed.

2.7 Annexes and Appendixes

2.7.1 Annexes

DOE	U.S. Department of Energy
HO	Hanford Operations
MEL	Mobile Energy Laboratory
OSB	Operations and Services Building
PNL	Pacific Northwest Laboratory
WHC	Westinghouse Hanford Company

2.7.2 Appendixes

Appendix A contains the Special Equipment Request, used when a property transfer of a MEL to PNL is initiated.

Appendix B contains the Assignment and Justification Questionnaire.

Appendix C contains the Equipment Tracking Form.

2.8 Delivery Requirements

The transfer and preparation of the MELs and contained equipment results in a MEL that is ready for transportation to an assigned site and contained equipment that is in peak operating condition and ready for testing at the site.

Special Equipment Request

Contractor Battelle, Pacific Northwest Laboratory		SPECIAL EQUIPMENT REQUEST	
Controlling Component WMC, Fleet Management		Deliver To GB Parker	
Requesting Component PNL		Area 3000	
Operating Component Facilities		Room 2400STV 2338	
		Est Date 07C33	
Equipment Requested Mobile Energy Laboratory			
Description - Specification of Equipment 1967 Flexible Coach. This laboratory is used as a portable workstation for up to six engineers/technicians to perform energy metering analysis and survey. This laboratory is outfitted with 16 tool cabinets, work tops and 2 work tables. Equipment included in this laboratory are steam/fluid flow & electrical metering equipment, calibration and troubleshooting equipment, combustion testing equipment and computer support equipment.			
Give Details as to needs for the Equipment and Alternate Solutions Considered The U.S. Department of Navy has transferred this Mobile Energy Laboratory to the custody of Battelle.			
Impact if Equipment is not received Contract requirements cannot be filled.			
<div style="text-align: right;">AR Gahmer</div> <div> Originated By GB Parker </div> <div> Date 5/16/89 </div> <div> Approved By LD Kannberg </div> <div> Date 5/16/89 </div>			
DISTRIBUTION: Original to Controlling Component - Other Copies as Requested			

Appendix B

Assignment and Justification Questionnaire

ASSIGNMENT AND JUSTIFICATION QUESTIONNAIRE LIGHT AUTOMOTIVE VEHICLE		H.O. Number _____	
PLEASE PRINT OR TYPE		Equipment Type Mobile Energy Laboratory	
1. Person Directly Responsible for Control of This Vehicle		License No. E-	
Name Graham B. Parker Tel. No. 375-3805		ASSIGNMENT	
GB		Contractor Battelle	
Title Project Manager		Department/Division Energy Sciences	
Location 2400 Stevens MSIN K5-20		Organization	Cont Code 07C33
2. Is vehicle used for motor pool service? ☐ Yes ☒ No If not, could it be pooled? ☐ Yes ☒ No If answer to both questions is no, explain in section 6.		Vehicle located at Area 3000 Building 2400	
3. This vehicle is used regularly for:			
☐ Pool for Building Occupants ☐ Inspect Work in Progress ☐ Transport Supervisor ☐ Pool for Organization Members ☒ Transport Tools/Equipment ☐ Emergency Standby ☐ Use Limited to 1-3 People ☐ Transport Material ☐ Emergency Response (Fire/Patrol) ☐ Travel to Meetings ☐ Transport Craftsmen ☐ Other			
4. This vehicle travels to the following location on a regular basis (at least once per week). List Building/Area. _____ _____			
5. Is vehicle driven on swing or graveyard shift? ☐ Yes ☐ No			
6. Provide additional details on how the vehicle is used, especially how the vehicle supports the job performance of the regular users. <u>This laboratory is used as a portable work station for up to six engineers/</u> <u>technicians to perform energy metering analysis and surveys. This laboratory is out</u> <u>fitted with 16 tool cabinets, work taps and 2 work tables.</u> _____ _____			
7. List all specific equipment installed on this vehicle such as: special cab or bodies, compressors, tanks, racks, tailgate lifts, etc. List WA Number for radios. <u>Equipment included in this laboratory are steam/fluid flow and electrical</u> <u>metering equipment, calibration and trouble shooting equipment, combustion testing</u> <u>equipment, and computer support equipment.</u> _____			
8. Is this unit the proper one for the work being performed? ☒ Yes ☐ No If not, list a more suitable unit.		9. Is this equipment contaminated? ☐ Yes ☐ No ☐ Regulated ☒ Nonregulated	
Prepared By Annet L. Dittmer		Reviewed By (Manager) <i>GB Parker</i> <i>L.D. Kennedy</i>	
Phone 375-3783	Date 5/15/89	Phone 375-3919	Date 5/16/89

Appendix C

Equipment Tracking Form

Destination: _____

Date: _____

Name: _____ Assigned to: _____

Type of Equipment.

[illegible]

Mobile Energy Laboratory

Procedure 3.0

Equipment Inventory, Repair, and Accountability Guidelines

3.0 Equipment Inventory, Repair, and Accountability Guidelines

3.1 Introduction

This procedure provides guidelines for the inventory, calibration/repair, and accountability of the equipment assigned to the Mobile Energy Laboratories (MELs). These guidelines ensure that MEL equipment is in optimum operating condition at all times.

3.2 Scope

Common operational procedures are provided as a basis for effectively controlling the condition and location of the property belonging on the MELs. Inventory and property control forms are provided to ensure that appropriate information is given to maintain the equipment at its optimum operating level. Procedures are also provided for the calibration/repair of the MEL testing equipment.

3.3 Referenced Documents

Statham Division of Solartron Transducers. *Gould PG3000 Series Instruction Manual*. Oxnard, California.

3.4 Summary of Procedure

The flowchart shown in Figure 3.1 is a simplified expression of the flow of activities necessary to determine the condition and accountability of the property assigned to the MEL.

3.5 Significance and Use

This procedure is specifically designed as a guideline to effectively maintain the MEL equipment at optimum operating efficiency and as a guide to property control accountability.

3.6 Calibration and Standardization

Calibration and standardization activities are an integral part of the overall equipment procedure. The frequency of calibration is determined at the time of the initial inventory for each piece of equipment requiring calibration, which is tracked on the Equipment Tracking Spreadsheet (see Appendix A for an example). The Pacific Northwest Laboratory (PNL) Property Control Custodian shall ensure that all calibrations are completed when scheduled or as needed. All testing equipment shall be removed from the MELs to the Metering Laboratory in the 2400 Stevens Building at PNL. The equipment shall be carefully checked by qualified PNL technicians. Equipment needing calibration or repair shall be noted and remain in the calibration procedure.

Figure 3.1. Flowchart of Activities to Determine MEL Property Condition and Accountability

3.7 Procedure

This procedure describes the steps required to track and maintain all property assigned to each MEL.

3.7.1 Inventory

A physical inventory shall be performed by the assigned MEL Property Control Custodian and one assigned technical staff member upon possession of a MEL. The following information shall be tabulated for all accountable MEL equipment on an Initial Equipment Inventory (see Appendix B):

- category
- manufacturer
- model
- quantity
- serial number
- plant accounting number

- Naval Energy and Environmental Support Activity (NEESA) number
- condition.

The condition of the equipment should be noted with careful attention given to the following:

- damaged/lost equipment
- obsolete equipment
- equipment requiring calibration/repair.

After the inventory is completed, the information is transferred to the Equipment Tracking Spreadsheet by the MEL Property Custodian.

3.7.2 Equipment Tracking Spreadsheet

All inventories performed after the initial inventory shall be completed using a Standard Equipment Inventory form (see Appendix C). This form is a modified version of Appendix B that does not include the NEESA number or the plant accounting number because the equipment has been assigned a PNL number. All information collected during an inventory shall be transferred to the Equipment Tracking Spreadsheet. PNL Property (Expense) tags, with the MEL number and the SD number for this project printed on the tags, shall be affixed to all equipment on the MELs. The numbering system is as follows:

- Numbers on the MEL obtained from the U.S. Army are ARM-001
- Numbers on the MEL obtained from the U.S. Air Force are AF-001.....
- Numbers on the MEL obtained from the U.S. Navy are NAV-001.....
- Numbers on the MEL obtained from DOE are DOE-001.....
- MEL equipment not assigned to a MEL is numbered MEL-001.....

Equipment with a purchase price over \$3000 and automatic data processing equipment (ADPE) (computers and sensitive equipment) shall be tagged and tracked by PNL Property Management and the MEL Property Custodian.

Hand tools on the MEL shall be inventoried during the equipment inventory and listed in the category Tool/Misc. This information is entered on the Equipment Tracking Spreadsheet by the PNL MEL Equipment Custodian. Expendables shall be inventoried during the equipment inventory and listed in the category as Tools/Misc. This information is entered on the Equipment Tracking Spreadsheet by the PNL MEL Equipment Custodian.

3.7.3 Calibrating/Repairing Equipment

3.7.3.1 PNL-Based Calibration

When MEL equipment is at PNL and needs to be calibrated or repaired at the WHC Standards Laboratory, a delivery tag (see Appendix D) must be filled out and securely attached to the equipment. Any special requests must be included on the tag. A manual should accompany new items being sent to WHC. Call WHC Transportation to schedule a driver to pick up the equipment. WHC notifies the PNL Property Control Custodian when the calibration/repair is completed and delivers the equipment to the 2400 Stevens Building.

3.7.3.2 Non-PNL Calibration

If the WHC Standards Laboratory is unable to do the calibration or repair, complete a PNL Purchase Requisition to request that the manufacturer repair or calibrate the equipment and send the requisition to the PNL Procurement Department for processing. Equipment that is to be calibrated or repaired by the manufacturer shall be packaged and mailed by WHC. A PNL Return Order must be completed and a radiation survey performed.

3.7.3.3 Calibrations by MEL Staff

The Gould PG3000 Series Gage Pressure Transmitter, Statham Division of Solartron Transducers, Oxnard, California, does not require calibration or repair by the WHC Standards Laboratory or the manufacturer.^(a) This equipment shall be checked out, calibrated, and repaired according to the procedures in the Gould PG3000 Series Instruction Manual by a qualified PNL technician.

3.7.3.4 Calibrating Off-Site Equipment

When off-site equipment requires calibration or repair at the WHC Standards Laboratory, it is mailed to the MEL Property Control Custodian and sent to the WHC Standards Laboratory. If any equipment fails or requires calibration while off site, call the PNL Operations and Services Building (OSB) Receptionist and request a telephone emergency purchase requisition. The required information may be given over the phone and approvals may be made for the manufacturer to perform the repairs or calibration.

3.7.4 Equipment Disposal

Any equipment that is lost or damaged beyond use is disposed of in accordance with PNL property management guidelines.

-
- (a) References to specific manufacturers and models are not to be construed as an endorsement as compared to equivalent instrumentation available from other manufacturers.
-

3.7.5 Equipment Upgrades

When any of the equipment on the MEL is not adequate for the type of testing to be done and improved equipment has been developed, the improved equipment may be purchased by following PNL purchasing procedures through the PNL Purchasing Department.

3.7.6 Excessing Equipment

Equipment no longer needed for testing applications is returned to the U.S. Department of Energy (DOE) operating agency for disposal according to their procedures.

3.8 Annexes and Appendixes

3.8.1 Annexes

ADPE	automatic data processing equipment
DOE	U.S. Department of Energy
MEL	Mobile Energy Laboratory
NEESA	Naval Energy and Environmental Support Activity
OSB	Operations and Services Building
PNL	Pacific Northwest Laboratory
WHC	Westinghouse Hanford Company

3.8.2 Appendixes

Appendix A contains the Equipment Tracking Spreadsheet, used to track equipment calibration requirements.

Appendix B contains the Initial Equipment Inventory form, used to document information obtained from an initial equipment inventory.

Appendix C contains the Standard Equipment Inventory form, used to document information obtained after the initial inventory.

Appendix D contains the delivery tag that is attached to equipment being calibrated or repaired at WHC.

3.9 Testing Schedule

The frequency of scheduling calibrations and repairs for MEL equipment varies depending on the particular equipment, duration of use, and amount of time between assignments. Equipment requiring calibration shall be closely surveyed to determine calibration accuracy.

3.10 Delivery Requirements

All calibrations or repairs of testing equipment shall be performed in a timely manner to ensure testing is completed on schedule at an assigned site.

Equipment Tracking Spreadsheet

CATEGORY	DESCRIPTION	MANUFACTURER	MODEL	QUAN- TITY	SERIAL NUMBER	PH. NO.	NEEDS CALIB.	CALIB. PRICE	CALIB. DUE DATE	OWN TO CALIB.	CALIBRATION NO.	SENT TO CALIB.	RETURNED 010P001
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	067010000		YES						
ELECTRICAL	ISOLATION TERMINAL BOX			1	040100000	AF-041							
ELECTRICAL	ARMATURE			1	04-007140								
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0000	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0000	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0000	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0007	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1									
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-010							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0001								
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0000	AF-001							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1									
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-004							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-010							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0137	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0002								
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-001							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1		AF-007							
ELECTRICAL	CURRENT TRANSFORMER	BRANETZ		1	0004	AF-000							
ELECTRICAL	CURRENT TRANSFORMER	ALSC	W101	1		AF-004							
ELECTRICAL	LEADLINE PROTECTION			1									
ELECTRICAL	LIGHT METER			1	0400								
ELECTRICAL	PANCAULT KIT	PANCAULT		1									
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	140170000	AF-010	YES					7/30/00	
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	140100000		YES						
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	007A000075		YES						
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	140100000		YES						
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1			YES						
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	140170000		YES						
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	140107000	AF-017	YES		6/30/01	BRANETZ	7/30/00	0/30/00	
ELECTRICAL	POWER DEMAND ANALYZER	BRANETZ		1	000A000410	AF-010	YES					7/30/00	
ELECTRICAL	BLINDING GLOVES			1									
ELECTRICAL	SAFETY POWER PHONE			1									
STEAM	DRILL BIT			1									
STEAM	DRILL BIT			1									
STEAM	CHKS DATA CABLE			1									
STEAM	CHKS POT			1	M0001 00		YES						
STEAM	CHKS POT			1	L0700 00		YES						
STEAM	CHKS POT			1	M0000 00		YES						
STEAM	CHKS POT			1	M0070 00		YES						

Initial Equipment Inventory

Date Issued:
September 1993

Page
B.1

**Mobile Energy Laboratory Procedure 3.0, Appendix B
Equipment Inventory, Repair, and Accountability Guidelines, Version 1**

Standard Equipment Inventory

Date Issued: September 1993 **Supersedes Issue Dated:** **Page** C.1 **Mobile Energy Laboratory Procedure 3.0, Appendix C**
Equipment Inventory, Repair, and Accountability Guidelines, Version 1

Appendix D

Delivery Tag

RELEASE
FOR
READY

000000
000000
NOT

DELIVERY TAG

TO _____
BLDG. _____ DATE _____
INV. NO. _____
H. W. NO. _____
FROM BLDG. _____
REMARKS _____

OVER

TO _____
BLDG. _____ DATE _____
VIA _____
INV. NO. _____
H. W. NO. _____
REMARKS _____

SENDER

54-3000-239 (11-65) U813330

GPO 594-175

Mobile Energy Laboratory

Procedure 4.0

Safety Operation Plan

4.0 Safety Operation Plan

4.1 Introduction

This Safety Operation Plan is designed for use with all Mobile Energy Laboratory (MEL) work performed at Pacific Northwest Laboratory (PNL) and federal or other installations. The plan should be used in conjunction with any applicable center, departmental, or laboratory safety plans. Any applicable local or state safety requirements should also be considered when performing potentially hazardous work.

4.2 Scope

This plan, while outlining a set of standard safety practices for MEL work, also includes provisions for initial and refresher safety training in specific tasks and work areas.

4.3 Summary of Procedure

Safety practices for specific tasks performed by the MELs are detailed below. Where a MEL work procedure for a specific type of task exists, the applicable safety section in this plan should be included as a part of that procedure.

4.4 Significance and Use

This procedure is specifically designed as a guideline to ensure safe operating procedures are followed while performing all MEL work at PNL, on MEL buses, and on off-site facilities.

4.5 Procedure

This procedure outlines a set of standard safety practices and provisions for initial and refresher safety training in specific tasks and work areas to be used while performing MEL work.

4.5.1 Safety Practices at PNL

The following outlines safety practices for work performed at PNL.

4.5.1.1 General Shop Practices

General shop safety practices shall be followed at all times. These practices shall cover items such as housekeeping, personal protective equipment, and special equipment as outlined in PNL safety manuals.

4.5.1.2 Lifting Heavy Objects

Safety procedures and cautions for lifting heavy objects may be found in PNL safety manuals. MEL staff shall be familiar with the cautions regarding lifting and carrying, weight limits, medical restrictions, and environmental factors.

4.5.1.3 Fire Hazards

Staff shall be responsible for identifying fire hazards in all working areas and knowing the correct type of fire extinguisher to use for a specific hazard. Electrical equipment extinguishers are classified as Type C, and extinguishers for ordinary combustibles, such as paper, are classified as Type A. Staff shall be aware of where each type of fire extinguisher is located within a working area. General fire hazard information is contained in PNL safety manuals. If a fire should occur while at the Laboratory, call the emergency number 375-2400 to report it.

4.5.1.4 Operating General Laboratory Equipment

General electrical equipment used in the Laboratory by MEL field personnel includes electric drills, band saws, belt sanders, grinders, ladders, soldering irons, and other power hand tools. The manuals for the equipment used shall be housed with or near the equipment itself. Staff shall read and understand the manuals before using any of the equipment. General laboratory equipment shall be checked at a minimum of every 12 months for proper grounding, exposed wiring, worn cords, and general safe operating condition. Any unsafe equipment shall be identified and removed from service until repaired.

4.5.1.5 Safety Wear and Equipment

The safety wear and equipment available for use in the Laboratory shall include safety goggles, gloves, fire extinguisher(s), and hearing protectors. Refer to equipment manuals for recommended safety wear use. The location of fire alarms and emergency exits shall be noted by all personnel using the Laboratory. Laboratory equipment and tools shall be checked at a minimum of every 12 months for proper grounding, exposed wiring, worn cords, and general safe operating condition. Any unsafe equipment shall be identified and removed from service until repaired. High-voltage gloves shall be air tested each year and before use, and tested according to current American National Standards Institute (ANSI)/American Society of Testing and Materials (ASTM) methods every 6 months. Equipment checking and testing shall be scheduled and associated records kept by MEL calibration technicians.

4.5.2 Safety Practices on MEL Buses

Work performed on MEL buses is similar in nature to that performed at the Laboratory. All applicable safety practices from Section 4.6.1.1 shall also apply on MEL buses. Additional specific practices are detailed below.

4.5.2.1 Driving

- Observe all applicable safety practices described in Section 4.6.3.1.
- Buses shall be driven by qualified personnel ONLY. This qualification shall include a current bus driver endorsement (over 26,000 gross) as administered by the appropriate state department of licensing.
- Whenever a bus must be maneuvered or run in reverse, a second person shall be present outside the bus to function as a guide.
- Any non-PNL personnel that are subcontracted or otherwise authorized to drive the bus shall have the same qualifications discussed above and must carry their own insurance and/or bonding.

4.5.2.2 Safety Practices On or Around MEL Buses

- Observe all applicable laboratory safety practices discussed in Section 4.6.1.
- MEL buses shall be parked on level, solid ground with parking brakes applied prior to beginning any work on or around the bus. No electrical or other hazardous work shall be performed while the bus is in motion.
- All equipment shall be securely stored and locked inside drawers or outside compartments when not in use and while bus is in motion.
- Field work equipment on the bus shall be checked at a minimum of every 12 months (or before equipment is used again) for proper grounding, exposed wiring, worn cords, and general safe operating condition. Any unsafe equipment shall be identified and removed from service until repaired. High-voltage gloves shall be air tested before use and tested according to current ANSI/ASTM methods every 6 months. Equipment checking and testing shall be scheduled and associated records kept by the MEL calibration technicians.

4.5.2.3 Safety Wear and Equipment

Each MEL bus shall carry the following safety wear and equipment: fire extinguisher, flares, hard hats, high-voltage and regular gloves, goggles, and hearing protectors.

4.5.3 Off-Site Safety Practices

While off site and during off hours, staff shall locate safety devices, such as fire extinguishers and emergency exits, located within the facility. Emergency phone numbers shall also be noted.

4.5.3.1 Driving

- State and federal traffic laws shall be observed.
- PNL safe driving rules, described in PNL safety manuals, shall be observed. Maintenance of buses should only be performed by qualified service personnel.
- While driving to or between sites, the staff member is considered on the job. Thus, drinking alcoholic beverages prior to operating a vehicle is viewed in the same terms as drinking on the job. At the end of the workday, when staff members are within walking distance of their hotel/motel rooms or are taking a cab, consumption of alcohol is at the reasonable discretion of the staff member.
- If an automobile accident occurs, accident report forms must be filed both with the state in which the accident occurs and PNL. PNL accident reporting procedures should also be followed.

4.5.3.2 Safety Wear

A safety kit that includes high-voltage and regular gloves, hard hats, hearing protectors, and goggles shall be available at the Laboratory. The kit shall be taken and used on all field installations or removal trips where a fully equipped bus is not being used.

4.5.3.3 Electrical Panels, Substations

- Safety procedures and cautions for working on electrical panels are found in PNL safety manuals.
- PNL staff working within electrical panels and substations must have knowledge of electrical fundamentals through formal or laboratory training. The individual's qualifications shall be documented by the project manager. Work installed in, or performed on, electrical panels and components shall be done with respect to standard safe electrical practices (National Electric Code [NEC] or equivalent) and any specific site requirements.
- For high-voltage work (over 120 V), two qualified individuals must be present when accessing the service panels (one to render assistance should the other be harmed). For lower voltage systems (120-V residential work), the qualified individual may work alone. Goggles or safety glasses and protective gloves should be worn.
- All connection/disconnection work inside any substation or other switching station equipment shall be performed by on-site electrical staff or a contracted equivalent that is approved by the site electrical supervisor.
- Extreme caution shall be used when humid conditions exist. Protective gloves are strongly recommended. Extra care should also be taken while on concrete floors because it is virtually

the same as standing on the ground. A rubber floor mat or equivalent may be required when accessing panels on concrete floors. Individuals should not work in electrical panels if they are wet or sweaty or the surrounding area is wet or damp.

- A tag-and-lock procedure, outlined in PNL safety manuals, should be used when de-energizing systems. Controls that may cause unsafe conditions while working on energized systems should also be tagged and/or locked. Potentially dangerous equipment that is left in place on site shall be tagged according to procedures for continued safety of on-site personnel.

4.5.3.4 Steam and Chilled Water Production and Distribution

- Secure footing, such as permanent platforms and sound scaffolding, should be present around elevated steam/chill work areas. Site erected scaffolding shall be checked for unsafe conditions prior to use. Toeboards and attached ladders and handrails should be present and firmly attached whenever possible. The use of fall protection belts/ropes are recommended when working in awkward positions or where complete railings cannot be placed. The use of free-standing ladders, excessive reaching, and unstable platforms shall be avoided.
- Two persons trained in steam/chill system safety practices or functioning as steam/chill system operators shall be present when work is being performed on pressurized/operating steam/chill lines or components.
- Steam/chill plant or system operators shall be made aware of all work being performed on the system to avoid system changes that may cause unsafe conditions. A tag-and-lock procedure, outlined in PNL safety manuals, should be used on shutdown systems. Controls that may cause unsafe conditions while working on running systems should also be tagged and/or locked. Potentially dangerous equipment that is left in place on site shall be tagged according to procedures for continued safety of on-site personnel.
- Safety glasses or goggles and gloves shall be worn by all personnel while operational system lines or components are being tied into, which shall include tap drilling and insertion and extraction of probes and sensors.
- Hard hats shall be worn by all personnel working in areas subject to bumping or falling hazards and in all posted "Hard Hat" areas.
- Ear protection shall be worn by all personnel working near any noisy operating equipment, such as large boilers, chillers, and motors.
- All manufacturers' safety notations and cautions shall be observed for safe operation of all hot-tap equipment. The applicable MEL test procedure and manufacturer's procedure manual(s) for hot-tap work and equipment should be reviewed by all involved personnel.

4.5.3.5 Field Work Equipment

Field work equipment and tools shall be checked at a minimum of every 12 months for proper grounding, exposed wiring, worn cords, and general safe operating condition. Any unsafe equipment shall be identified and removed from service until repaired. High-voltage gloves shall be air tested each year and before use and tested to current ANSI/ASTM methods every 6 months. Equipment checking and testing shall be scheduled and associated records kept by the MEL calibration technicians.

4.5.4 Training

Training records, procedures, and other documentation shall be kept by the task manager for the duration of the MEL Program. These records include training and safety procedures, records of each field staff member's training status, training attendance records for training conducted through the MEL Program, annual equipment checks, and any other records indicating training, certifications, and endorsements.

- The Defensive Driving Laboratory Training Course must be taken by each individual who performs MEL field work. This training shall be renewed every 12 months. Quarterly briefs may be given for reminders on weather conditions, holiday traffic, and use of rental vehicles.
- Personnel who drive any MEL bus must maintain the required license endorsement as required by the appropriate state department of licensing.
- CPR training, which is offered through Kaiser Engineers or the Hanford Environmental Health Foundation, shall be taken by all individuals performing MEL field, bus, or laboratory work. This training shall be renewed at a minimum of every 2 years.
- Electrical, steam, and heating, ventilating, and air conditioning (HVAC) training conducted through MEL shall be renewed at a minimum of every 12 months by all personnel doing MEL field work. All field personnel or others that may visit potential work areas shall take all portions regardless of particular current task assignments. A training record, such as the briefing documentation form available from PNL Laboratory Safety, shall be used at each training session to document attendance and training content.
- Any other training deemed necessary because of programmatic or capability changes is required to be renewed at a minimum of every 12 months.

4.6 Annexes

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
HVAC	heating, ventilating, and air conditioning
MEL	Mobile Energy Laboratory
NEC	National Electric Code

Mobile Energy Laboratory

Procedure 5.0

Electrical End-Use Metering

5.0 Electrical End-Use Metering

5.1 Introduction

In most federal facilities, detailed electrical energy consumption information, particularly at the building level, is not available. The installation of supplemental data collection systems may be the only concrete mechanism to identify and/or confirm anomalous consumption patterns.

The rationale for electrical end-use metering (EEUM) will be well developed and identified as part of a general facility energy assessment. As part of that assessment, the kind and level of detail of end-use data will have been identified, as well as the expected results, which involves the creation of a detailed test plan for the expected activities, including analysis procedures. It is futile to attempt EEUM unless these precursory steps have been accomplished.

5.2 Scope

This procedure provides basic guidelines for conducting EEUM within targeted buildings. A range of possible protocols for EEUM may be applied, depending on the objectives of the data collection effort. Instrumentation protocols are under development by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) and the American Society for Testing and Materials (ASTM) to provide general guidance on how to approach the problem of end-use energy consumption data but, in all cases, the objective of the effort must be established prior to initiation of instrumentation.

5.3 Referenced Documents

Pacific Northwest Laboratory (PNL). 1989. *The Mobile Energy Laboratory Use Plan*. PNL-6861, Richland, Washington.

U.S. Executive Office of the President (EOP), Office of Management and Budget. 1987. *Standard Industrial Classification Manual*. National Technical Information Service (NTIS), Springfield, Virginia.

5.4 Terminology

There are no terms in this procedure that require new or other than dictionary definitions.

5.5 Summary of Procedure

The order and relationship of the required activities for EEUM is presented in a simplified flowchart shown in Figure 5.1. A more detailed explanation of each of these activities is provided in Section 5.10. As expressed above, it is assumed that the metering objective has been established prior to initiating the EEUM test.

Figure 5.1. Flowchart of Key End-Use Electric Metering Activities

5.6 Significance and Use

Metering of electrical consumption at the end-use level provides detailed information for assessments of facility energy consumption. Specific consumption levels can be identified for individual devices, or for particular end uses, to evaluate the cost-effectiveness of proposed retrofits.

Reasons for abnormal energy consumption can be explored, and impacts of operational or equipment modifications can be evaluated.

In addition, EEUM systems generally allow for the collection of consumption data at temporal resolutions sufficient for evaluations of high-demand billings caused by peaking problems.

5.7 Apparatus

The development of measurement plans (MPs) and the installation of an EEUM system requires a standard set of electrical and electronic instrumentation hand tools. Electrical measurement tools such as voltmeters, ammeters, and power guns are essential, as well as devices for circuit tracing. Portable radios greatly assist in the process of confirming wiring configurations and connections. A portable computer is required to communicate with the data logger to set parameters and verify installation.

The installation requires a set of test instrumentation including data logger(s), current transformers, indoor temperature sensors, and indoor relative humidity sensors. An outdoor weather station, consisting of sensors for measuring wind speed, ambient temperature, relative humidity, and solar radiation, may be needed if similar data is not available from either the facility or the National Weather Service. Current transformers are available in a range of sizes and ratings. Each installation requires a unique set to meet individual building configuration and metering objectives.

Data collection and processing requires a field data collection computer and a way of obtaining data from the building. Usually, this means that the building will require telephone communications with the data logger(s). Although routine data collection can be performed by site personnel, the initial phases of EEUM data collection shall always be performed by Mobile Energy Laboratory (MEL) personnel.

5.8 Hazards

The MEL Use Plan (PNL 1989) outlines a set of standard safety practices for all MEL work and specifically addresses electrical panel and substation safety issues in Section 3.3.

As a matter of general practice, it should be assumed that all on-site activities present a potential for personal injury. Prudent safety precautions shall to be taken at all times. Obtain and use (wear) whatever safety equipment is required, such as seat belts, safety glasses, hard hats, and hearing protectors.

5.9 Calibration and Standardization

The test equipment and sensors used in EEUM shall have specific maintenance and calibration requirements as specified by the manufacturer. All equipment shall be maintained in good working condition and calibrated periodically.

Maintenance and calibration records for the test equipment shall be maintained as part of the MEL project files.

5.10 Procedure

5.10.1 Completing Initial Site Survey

Complete an initial site survey (ISS) at each building that has been identified for EEUM. (See Appendix A for the ISS Procedure.) The primary objectives of the ISS are to determine whether a building is suitable for monitoring and to develop a cost estimate for monitoring. Collect detailed information about the building's electrical distribution system(s) (EDS), along with some basic information about the building in general. After the ISS is completed, the survey team shall estimate the full cost of monitoring and recommend whether the building should be accepted for EEUM.

5.10.2 Completing Site Characteristic Survey and Developing Measurement Plan

The site characteristics survey (SCS) consists primarily of a data collection effort conducted at the building. Collect information about the building as a whole, which includes each tenant, the electrical and gas loads, and the distribution equipment in the building.

Develop a plan for monitoring the building using information collected in the SCS about electrical loads and distribution equipment. MP development shall include assigning identified loads to logger channels, determining the number of channels and loggers necessary to meet the measurement goals of the project, itemizing hardware requirements, and specifying the location and type of monitoring equipment to be installed.

5.10.3 Installing Equipment

The MP developed for each building shall be implemented by installing a set of sensors and data logging equipment. Loading parameter sets and initializing data collection shall also be part of the installation process. Each building shall be subjected to a verification process to ensure that the installation activities have been performed correctly.

5.10.4 Collecting Data

Data shall be collected from the data loggers in a timely and efficient manner. Generally, this should involve interrogating the systems over telephone lines when the loggers are one-half full of data that has not previously been collected. This helps to ensure minimal data loss because of hardware problems.

The data collection process shall include automated checking for data quality and flagging of suspect data files. Standard aggregations shall also be conducted as part of the routine data collection process.

5.10.5 Maintenance

Review the data from each building on a routine basis for a range of different quality issues. If any of these tests fail, or if communication to buildings is disrupted, steps shall be taken to completely identify the nature of the problems and achieve solutions. In some cases, this may require extensive reworking of installations.

5.10.6 Removal

At the conclusion of each building's metering period, remove the metering equipment and associated sensors, and return the point of installation to at least its previous condition prior to metering. Repair damaged surfaces in visible portions of the buildings and patch all holes. Specific instructions are provided for the return of the monitoring equipment to the project inventory. Building files, both paper and electronic, shall be closed and retained as part of the MEL project files.

5.11 Calculation or Interpretation of Results

Data analysis activities are contingent upon the scope identified in the development of the test plan document.

5.12 Report

Prepare a brief written report for each building at the conclusion of metering. The content of the report shall be determined by the test plan prepared during the initial phases of the project.

5.13 Annexes and Appendixes

5.13.1 Annexes

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASTM	American Society for Testing and Materials
ECM	energy conservation measures
EDS	electrical distribution system
EEUM	electrical end-use metering
FDAS	Field Data Acquisition System
HVAC	heating, ventilating and air conditioning
ISS	initial site survey
kVA	kilovoltampere
MEL	Mobile Energy Laboratory
MP	measurement plan
NA	not applicable
PNL	Pacific Northwest Laboratory
SCS	site characteristics survey

SIC Standard Industrial Classification
VAV variable air volume

5.13.2 Appendixes

Appendix A contains the ISS Procedure.

5.14 Personnel Support

EEUM requires a team of individuals with a particular set of skills. The following paragraphs explore each of those skills in some detail. It is possible that certain individuals may have more than one of the required skills, allowing for a smaller team. The team shall include

- a team leader
- an electrician (an electrician licensed to perform work in the electrical area to be monitored)
- a technician (an individual familiar with the data logging equipment)
- a building auditor (an individual familiar with building auditing techniques)
- a site representative (an individual familiar with the particular electrical and mechanical systems at the building being monitored).

5.14.1 Team Leader

EEUM is a complex activity requiring several activities that must be accomplished in very precise ways. A single individual shall be identified to manage the work flow, make key decisions, and resolve questions.

5.14.2 Electrician

Installing EEUM monitoring equipment requires opening of electrical panels, disconnection of wires, and installation of current transformers on wires. These activities shall be performed by a licensed electrician familiar with the code and inspection requirements of the local jurisdictions.

5.14.3 Technician

The data logging equipment is a set of special devices that require an instrument technician with a unique set of skills to properly install and troubleshoot the equipment. A technician with a thorough understanding of these special devices is essential.

5.14.4 Building Auditor

Most projects require the collection of a set of building and equipment characteristic information to place the electrical end-use data in proper perspective. This kind of information should be collected by an individual familiar with building auditing techniques to ensure that the correct data is collected in an efficient manner.

5.14.5 Site Representative

EEUM is a very intrusive activity that requires temporary power disruptions and access to all areas of the facility to be monitored. A representative of the site that is familiar with the EDSs, mechanical systems, and other special requirements is essential.

5.15 Testing Schedule

The testing schedule for EEUM varies considerably because any individual test can encompass a wide variety of parameters and information. The following schedule is based on performing the end-use monitoring of a single building with three individual 16-channel data loggers. A simple characteristic survey of the building is also included to ensure that the end-use data is placed in the proper perspective. Some EEUM efforts require the collection of extensive streams of data and modifications of installations to accommodate new circumstances at the building for retrofit evaluations. This schedule reflects only the efforts necessary for the initial installation and delivery of preliminary results.

5.15.1 Initial Site Survey

After the site assessment has identified a particular building and set of issues that require electrical end-use consumption data for resolution, a preliminary survey of the building shall be done to ensure that EEUM will provide the expected answer at an affordable cost. An ISS should require one day at the building site and one day in the office for report preparation.

5.15.2 Site Characteristic Survey and Measurement Plan Development

The collection of detailed information about the building, its equipment, and electrical configuration should require two to three days at the building for data collection and circuit confirmation, and two days of office work for MP preparation and characteristic survey compilation. The work at the building shall require two individuals.

5.15.3 Installation and Verification

Installation and verification of each data logger should require approximately two days. Some concurrent activities are possible that may allow completion of the installation and initial verification in one week. Activities at the building should normally require two individuals, plus an electrician. Final verification shall require the collection of a stream of data, as well as analysis and reconciliation of the results. This final verification should take one week to one month, depending on the

complexity of the installation, which usually involves several days of analytical effort and one or two days of field activity.

5.15.4 Data Collection

Data collection is straightforward from a properly verified and operating installation. If phone lines are installed, data collection should take two hours per week. The initial steps of data processing shall be done as part of the data collection effort. This should include examination of the data for obvious errors and construction of data aggregations to create "ready for analysis" data sets. Data collection and processing activity for each logger should take about two hours. If problems are identified, the time required for diagnosis should require one or more days, depending on the complexity of the problem.

5.15.5 Data Analysis

The time required for data analysis is dependent upon the initial objective of the end-use data collection as identified in the assessment. Creation of end-use summaries from the data sets can be done in one day or less. Evaluations of conservation options with calibration of simulations could take one week per option.

5.15.6 Report Preparation

The time required for report preparation is dependent on the extent of the analysis performed. It may take from one day to one month, or more.

5.15.7 Maintenance

For each year that a logger is installed, schedule three separate days for maintenance at the site. If retrofit activities are expected in the building, add three field days for each retrofit action to correct installation problems, plus time for verification and analysis.

5.15.8 Removal

The entire system should be removed and the building restored to reasonable conditions in two days.

5.16 Delivery Requirements

Deliver the results of the EEUM effort to the site contact at the conclusion of testing and analysis. The scope and content of this deliverable shall be contingent upon the requirements of the test as identified in the initial test plan.

Appendix A

Initial Site Survey Procedure

A.1 Overview

An Initial Site Survey (ISS) has two primary objectives:

- 1) to obtain sufficient preliminary data about each site to ensure that the site is suitable for monitoring
- 2) to develop a cost estimate for completing an audit, measurement plan, and full installation at the site.

When conducting an ISS during electrical end-use metering (EEUM), limited preliminary data about each site must first be collected so that the sites can be classified. This data is gathered during a brief visit of each potential site where a walk-by survey is performed. The ISS is then completed at each site that is successfully recruited. During the ISS, information is obtained about each building's electrical and gas (if present) distribution system(s), as well as general building and site information. When the ISS is completed, the survey team estimates the full cost of monitoring the site and recommends acceptance or rejection.

A.2 Site Rejection Criteria

One important goal of the ISS is to identify sites that are inappropriate for the data collection effort so they may be deleted. A site may be rejected by PNL, the site owner, or a site tenant.

During the walk-by survey, sites with severe problems (e.g., buildings that have been torn down) or sites that are predominantly occupied by business types not being considered in the study shall be identified and removed.

A site may be rejected during the ISS for several reasons. A site owner or tenant may refuse to participate because of concerns about privacy or inconvenience. The estimated cost may be too great for the value of the data that will be collected. PNL may recommend rejection of the site because of safety concerns or end-use mixing. Additional reasons for rejection include:

- Owner/Tenant Rejection
 - privacy
 - inconvenience
 - legal liability
 - safety
 - aesthetics
 - value

- other concerns.
- **PNL Rejection**
 - safety
 - value
 - inadequate documentation
 - excessive panels/circuits
 - manufacturing/industrial activity dominating or sharing loads with commercial activity
 - legal liability
 - other concerns.

Complete a Site Rejection Form (see Exhibit A.1) for all rejected sites. Enter the rejecting party, reason(s) for rejection, and a brief explanation of the nature of the problem at the site.

A.3 Preliminary Preparations

Prior to walk-by data collection, existing data about the location of each site should be used to develop a plan for executing the walk-by surveys.

A.3.1 Available Data

Data initially available for each site to be surveyed include

- one or more site addresses (at least one service address associated with each account at the site)
- firm name (name of largest firm at site)
- business type.

A.3.2 Walk-By Plan

Printouts of available data for each site shall be generated, sorted by city and ZIP code, and grouped according to geographical location.

Obtain maps for each county where sites are located. Using printouts of site addresses, locate and mark each site on the maps. Use these maps to develop a plan for visiting all of the sites and to locate the sites in the field.

A.3.3 Items Required for Data Collection

Before going into the field each day, ensure that the following items are available:

- map(s)
- list of site addresses

- walk-by survey forms (include extra copies)
- camera and film
- paper clips

A.4 On-Site Data Collection

On-site data collection includes the identification of all buildings at a site and the completion of a Walk-by Building Survey Form (see Exhibit A.2) for each building. To collect data, walk around the buildings at the site. Entering public access areas, such as building lobbies, is permitted, but do not attempt to gain access to restricted or private areas. The object of the walk-by is to collect a limited amount of information without gaining special access to any site areas or buildings.

A.4.1 Identifying Site Buildings

Upon arrival at a site, determine the number of buildings at that site. For the purposes of this study, a site consists of one or more buildings within the same block that are jointly owned and operated.

Sites can contain more than one business. For example, an office park may contain many buildings, each occupied by a number of tenants. However, if all of the buildings are owned and operated by the same property management or development firm, then all the buildings are part of the site.

A.4.2 Completing Walk-By Building Survey Form

One survey form is required for each building at the site. When the buildings at a site have been identified, enter the site identification (ID) (from the printed list of sites and addresses) and building number at the top of each page of the form. The building number for the first building at a two building site is Building 01 of 02. The building number for the second building at the site is Building 02 of 02. Record the date (month/day/year) and surveyor initials on the first page only.

- **Problem sites** - If a site cannot be located, or a severe problem with the site is encountered, enter the site ID, date, and initials, and complete the problem site block, briefly noting the nature of the problem. Leave the remainder of the survey form blank.
- **Building addresses** - Record the number, street name, and directional prefixes (e.g., NORTH 1st Street) and suffixes (e.g., 1st Street NORTH) in the appropriate spaces. Record the street address for each side of the building that has a public entrance. If a building has multiple addresses on one street, the starting number and ending number should be entered (e.g., 406 - 418 Main Street).

- **Number of above grade stories** - Record the number of above grade stories. Use the lowest grade line as "ground level." Include any ground floor that is partially below grade, but has at least 50% of its wall area above grade.
- **Building identifier** - Record a name that can be used as a building identifier because it may be easier to remember a site by name instead of site ID (e.g., building name - Transamerica Building or largest tenant - Safeway). It may also be desirable to include a location, such as Oakland 7-Eleven. This building identifier should be treated as sensitive information.
- **Number of businesses** - Record the number of businesses that occupy space in the building, which includes each business having a unique name. If the number of businesses can be counted by signs posted on the outside of the building or from a building directory, then enter that number. If the number type is classified as OTH or UNK in Item 5b of the form, explain why. In multiple building sites, this information is used to help determine which buildings will be end use monitored and will be important for multiple building sites that are distant from the field office.
- **Site plan sketch** - The site plan sketch shall be completed once for each site on the survey form for Building Number 01. Make a rough sketch of the site, showing all buildings surveyed. Each building must be labeled with its correct building number. In addition, the sketch should show orientation and street names of adjoining streets. Ensure that the sketch is clear because it will be used in the ISS to help identify the buildings at the site.

A.4.3 Building Picture

Photograph each side of the building, ensuring that the entire face is in the picture. For easy identification, the first picture of the building should show the firm name or some other distinctive feature. Develop the film immediately after the roll is used. Date and number the rolls sequentially so that negatives can be easily found at a later date. Note the site ID and the film roll number on the back of the photos and attach them to the survey form.

A.5 Initial Site Survey

The ISS consists of one or two brief on-site visits by a field engineer and an auditor. Prior to the site visit, schedule an appointment with the site representative, and computer generate and assemble the necessary data collection forms.

A.5.1 Scheduling Site Visit

Once the site representative has been briefed about the project and has indicated interest in participating, schedule the ISS site visit.

A.5.2 Generating Data Collection Forms

Before leaving the field office, the auditor shall obtain a complete set of site-specific data collection forms for the ISS. The computer automatically generates a package of the required forms for the desired site. Because these forms contain some previously obtained information for verification purposes, it is important that the auditor generate forms for the correct site.

In addition, the field engineer should obtain a copy of the site plan sketch completed during the walk-by for reference during the ISS.

A.5.3 Meeting with Site Representative

Upon arrival at a site, the survey team shall meet with the site representative. This task is to be completed for each site, regardless of the number of buildings at the site. The survey team should briefly explain to the site representative the purpose of the visit, which shall include:

- approximate duration of visit
- information that will be collected
- site representative's requirements

A.5.4 Site Tour

After interviewing the site representative, request a short tour of the site.

A.5.5 Verifying Site Plan Sketch

During the site tour, verify that the site plan sketch prepared during the walk-by survey is accurate, specifically ensuring that all buildings can be located from the sketch. If the sketch is inaccurate, then it should be corrected. Any buildings not shown on the site plan sketch should be added and assigned a building number.

A.5.6 Noting Meter Locations

While touring the site, the auditor should note the locations of electric and gas meters, and indicate them on the site plan. The utility identification number on each meter should also be noted.

A.5.7 General Building Information Form

For each building at the site, the auditor should complete a General Building Information Form (see Exhibit A.3).

- Physical description - Record a brief physical description of the building, including any significant factors.

- **Floor area** - Record the total floor area of the building. If plans are available, the floor area can be obtained from the plans; if not, calculate the floor area. Section A.5.8 provides detailed instructions for calculating floor area.
- **Number of above grade stories** - Verify the number of above grade stories reported during the walk-by survey. If this information is inaccurate, make corrections in the space provided.
- **Number of tenants** - Verify the number of tenants reported during the walk-by survey. If this information is inaccurate, make corrections in the space provided.
- **Business types** - Circle all business types present in the building and record the total number of business types in the space provided.
- **Common space** - Indicate if common space is present in the building. Common space is defined as nonrentable space accessible to, or serving all, tenants in the building. This space may include, but is not limited to, lobby areas, rest rooms, mechanical or electrical rooms, hallways, stairwells, and elevators.
- **Vacant space** - Indicate if vacant space is present in the building. Vacant space is defined as rentable space presently unoccupied.
- **Primary business type** - Confirm the primary business reported during the walk-by survey. If this information is inaccurate, make corrections in the space provided.
- **Primary functional use** - Confirm the primary functional use reported during the walk-by survey. If this information is inaccurate, make corrections in the space provided.
- **Fuel type by end use** - The end uses to be monitored in this project are listed with reasonable fuel choices. For each end-use, circle the Primary fuel type used. For example, if the building's heat is provided by a gas boiler, but there are also portable electric heaters present, the specified space heat fuel type should be gas. If an end use is not present in the building, then select Not Present. If an end use will not be separately monitored in this building type, then select Not Applicable (NA). If OTHER is indicated for any end use, specify the fuel type used. If OTHER is indicated for the Space Heat end use, the site should be recommended for rejection. If a building uses dual fuels in one system, ask the site representative if the building may operate on gas only for the duration of the study. If the site representative refuses to ensure that one fuel type will be used, the site should be recommended for rejection.
- **Meter numbers** - Record the meter identification number for all meters serving the building. Separate spaces are provided for gas and electric meters.
- **Notes** - Note any factors that affect the building's potential as an end-use monitoring candidate. For example, the building may be a small outbuilding, have an unusually complex electrical distribution system, or be otherwise unsuited for end-use monitoring.

A.5.8 Floor Area Worksheet

The Floor Area Worksheet (see Exhibit A.4) is used to calculate the building floor area for entry on the General Building Information Form. This worksheet is intended to aid the surveyor in calculating an accurate building floor area, which can be used later to dimension the plans for the primary building floor plan sketch. The worksheet is not submitted with the ISS submittal package discussed in Section A.5.14.2.

Divide the building into a series of boxes or segments. Portions of the building that have a different number of stories should be assigned to separate segments. Measure the length and width of each segment with a measuring wheel, and record the length, width, and number of stories on the worksheet. Use the segment areas to generate total floor area.

For triangular or circular segments, the length, width, and measurement method shall be slightly modified. For circles, measure the diameter of the circle and record the resulting number in the spaces for both length and width. Record a C to indicate that this was a circular segment. For triangles, measure the longest side and record that dimension as the length, then measure the perpendicular distance to the widest part of the triangle and record that dimension as the width. Record a T to indicate that this was a triangular segment. Use the following equations to calculate areas for circles and triangles:

$$\begin{array}{ll} \text{Circle:} & \text{area} = (1/2 * L) * (1/2 * L) * 3.142 * \text{stories} \\ \text{Triangle:} & \text{area} = (1/2 * L) * W * \text{stories} \end{array}$$

After calculating the area of each segment, sum all segments to obtain the total building floor area and record this total on the General Building Information Form.

Sketch the building at the bottom of the worksheet showing the segments used to calculate the floor area.

A.5.9 Building Information

In the ISS, detailed information about the building is collected. The bulk of this information pertains to the electrical and gas distribution systems present in the building. Detailed floor plan sketches are also prepared.

A.5.9.1 Building Tour

The building contact person should provide a quick tour of the building, introducing any tenants and identifying the location and content of all electrical panels and meters. If gas equipment is present, the location of gas meters and gas equipment should be noted. During the tour, the field engineer and auditor should complete the following:

- General Building Information Form - During the tour, the General Building Information Form (discussed in Section A.5.7) shall be completed for the building.

- **Tenant Contact Information Form (see Exhibit A.5)** - The site representative should introduce the field engineer and auditor to each of the tenants in the building. A tenant is defined as a firm or business that occupies space in the building who may be the owner if the building is owner-occupied. Briefly explain the project to each tenant. A prewritten letter of introduction shall be provided by PNL to the site representative. The following provides guidance on completing the Tenant Contact Information Form:
 - **Firm/Contact information** - Confirm contact information collected for each tenant on the form. If this information is inaccurate, make corrections on a blank Tenant Contact Information Form.
 - **Tenant ID** - Assign a three character tenant ID that is unique within the building for each tenant.
 - **Business type** - Record the business type of the tenant. It is important to remember that the business type describes the economic activity of the business and not how the space is being used. The *Standard Industrial Classification (SIC) Manual* (EOP 1987) may be helpful in classifying businesses into the appropriate business type categories. If the business type is not one of the categories specific to this project (i.e., OFF, NFR, WAR, GRO, RES), enter OTH for Other or NCM for Noncommercial (i.e., residential or industrial).
- **Operational/Installation Constraints Form** - Question the site representative and tenants to identify operational constraints or installation complications that may impact further work at the site. The presence of these constraints or complications should be noted on the Operational/Installation Constraints Form (see Exhibit A.6). If additional issues are identified later in the ISS, they should also be noted on this form. If extremely severe problems are identified, the ISS should be aborted and the site recommended for rejection. Provide Site ID, Building Number, Date, Initials, and address the following:
 - **Installation constraints** - Note physical complications that may prohibit installation, such as:
 - high ceilings
 - impenetrable walls or floors
 - availability of space for a three-phase breaker for each service type for voltage references
 - availability of 120 V, single-phase power to operate the Field Data Acquisition System (FDAS)
 - safety concerns
 - **End use mixing** - Note poor end-use disaggregation, which may not be obvious at this stage of the ISS. The building contact, however, may be able to indicate severe end-use mixing if familiar with the electrical system.

- Excessive crowding - Note excessive crowding in the panels, which will not be obvious at this stage of the ISS. At the conclusion of the tour, return to panels that may be suspect. Indications that the panel may be crowded include:
 - panel is physically small
 - panel has half-height breakers
 - panel is old
 - all breaker locations in the panel are full
- Schedule limitations - Note hours when work is not possible because of periods of peak business. Special arrangements shall be made to gain building access during nonbusiness hours.
- Loads affected by power interruption - Circle devices present in the building that are adversely affected by power interruption or whose power CANNOT be disrupted.
- Special restart procedures - Note any equipment with special restart procedures that will be required during the installation of the monitoring equipment. Specifically ask about HVAC, computers, alarms, and refrigeration systems.
- Limited access areas - Note areas where access is restricted or escorts may be required.
- Aesthetic sensitivities - Record concerns that tenants may have regarding aesthetics. Specifically note if the monitoring equipment will need to be installed in an area of public access or where removal and restoration may be costly.

A.5.9.2 Concluding Tour

At the conclusion of the tour, thank the site representative, estimate the duration of the remainder of the visit, and promise to notify the site representative when the on-site activity is complete.

A.5.10 Preparing Basic Floor Plan Sketches

A basic floor plan sketch, showing dimensions and tenant boundaries, is required for each floor of the building. Dimensions and areas can be copied from the Floor Area Worksheet used to calculate the building floor area for the General Building Information Form.

In most buildings, all (or nearly all) of the floors have the same general outline. In these cases, time is saved if one scaled outline of the building is made, copying this outline for each floor and the roof on flat-top buildings.

To produce this general outline:

1. Draw a rough sketch of the shape of the building perimeter.

2. Dimension the sketch by consulting the Floor Area Worksheet.
3. Decide on a scale, based on the grid provided on the sketch sheet, that results in as large a sketch of the entire perimeter as will fit on the sheet.
4. Draw the outline neatly on a sketch sheet. Indicate the scale used on the sketch, as well as the directional orientation of the plan.
5. Make as many copies of this outline as there are floors in the building, as well as the roof, if flat.

The following information shall be included on all floor plans:

1. Mark off the outer dimensions of each tenant space (tenants, common areas, and vacant space) using the scale indicated on the outline.
2. Draw in the walls separating each tenant space and label the spaces with the three character tenant code from the Tenant Information Sheet. Common areas and vacant spaces should be treated as tenant spaces. Label common areas "COM" and vacant space "VA1," "VA2," etc.
3. Number floors sequentially from bottom to top, regardless of the grade line. Indicate whether the floor is above or below ground. If more than 50% of the wall area for a given story is above ground, then that floor should be specified as above ground.

These basic sketches, showing tenant spaces on each floor, shall be copied and enhanced with additional detail throughout the project. When the basic sketches are complete, make a copy for each floor.

On the copied set of floor plan sketches, prepare an energy system components sketch, noting all electrical distribution equipment such as meters, panels, and switchgear. Also note the locations of gas meters and major gas-burning equipment; e.g., boilers, stoves, ovens, unit heaters. Show equipment located on the roof, such as rooftop gas package units, on a rooftop sketch. Piping runs from gas meters to equipment should be indicated on the sketch to help with development of the gas measurement plan.

In buildings with a large amount of electrical distribution and gas-fired equipment, two sketches can be prepared at the surveyor's discretion.

A.5.11 Riser Information Form

Information about the electrical distribution system in the building is to be recorded on the Riser Information Form (see Exhibit A.7). A riser diagram depicting the electrical distribution network in the building, from the service main to the individual service panels, should be drawn. Nodes, which are each piece of electrical distribution equipment (meter, transformer, switchgear, panel), should be

named and identified on the riser diagram in a manner consistent with building plans, and physical panel and switchgear labels. In addition, the riser diagram should contain the voltage configuration at the main connections between nodes.

The correct voltage configuration shall be identified at the ISS because specialized hardware and installation procedures affect measurement plan development.

Data about each node in the diagram shall be recorded as follows:

- Node type - Indicate the type of node to be described (panel, meter, switch, transformer).
- Node name - Record the node name that corresponds to the name used in the building and shown on the riser diagram.
- Voltage configuration - Record the voltage configuration.
- Volts - Enter the line-to-neutral voltage.
- Current rating/kilovoltampere(s) (kVA) - Indicate the current rating of the node if the node is not a transformer. If the node is a transformer, indicate its kVA rating.
- Served from - Indicate the node that serves this node. For service entrances enter Utility.
- Monitored - Indicate whether the node will be monitored. This information shall be completed for each node shown in the riser diagram. For transformers, the voltage configuration, volts, and current rating entered should be for transformer output. Input values for transformers shall be deduced from nodes located higher on the riser diagram.

If the building has gas-fueled equipment, a gas counterpart to the electric riser diagram shall be developed. This diagram should show gas meters and major pieces of gas burning equipment. At a minimum, each piece of equipment should be linked to the meter that serves it. If possible, the actual piping configuration (i.e. the connection of pieces of equipment to each other) should be depicted.

The standard Riser Information Form can be used for the gas riser diagram. When using this form, enter the gas meter identification number under node name and leave all other fields blank.

A.5.12 Identifying Nodes to be Monitored

After all nodes of the electrical distribution system have been identified, make a preliminary assessment of the nodes to be monitored and prepare a Preliminary Wattmeter Channel Requirements Summary Form (see Exhibit A.8) for these nodes. This assessment is the first attempt at the development of a rough measurement plan, but is intended primarily as a cost estimating tool.

When determining which nodes to monitor, several rules should be considered as follows:

1. The desired level of monitoring detail consists of end-use breakdowns by business type. Common space is treated as a separate business type. End-use loads serving more than one business type should be assigned to COM.
2. Monitoring should occur as high in the distribution network as possible, while still preserving the required level of detail. For example, it is preferable to monitor whole panels as one unit if all circuits in the panel serve the same end-use and business type.
3. End uses need not be entirely pure; some contamination is permissible. Up to 10% of the annual end-use load for a business type can consist of "noise"; i.e., other end uses that are not easily separable. For example, a panel that consists entirely of lights, except for a copying machine, can be monitored in its entirety and called lighting.

Using these rules as guidelines, consider each node in the distribution network and indicate on the Riser Information Form whether it will be monitored. When making these determinations, be conservative; i.e., overestimate the level of monitoring detail needed in situations where the optimal course of action is not readily apparent.

Each of the nodes to be monitored needs to be documented in further detail, using the Preliminary Wattmeter Channel Requirements Form to record the end uses served by each monitored node and the number of channels required for each end use. The channels required for each node are summed, and these totals are summed, for the building's total channel requirements. This documentation is not binding; it will be used to obtain a first estimate of the channel and logger requirements for the building.

Note concerns regarding the mixing of end uses, condition of the panel, and potential difficulty of installing current transformers or cabling on the Operational/Installation Constraints form.

A.5.13 Monitoring Gas Consumption

If the building contains gas equipment, then a measurement approach for this equipment shall be determined. The gas consumption may be ignored, measured directly, or measured by proxies.

If the gas consumption is measured directly, then the field engineer shall make a preliminary estimate of how many pulse-head meters are required for gas monitoring and where they will be installed during the ISS. These decisions are made in conjunction with a representative from the utility's gas metering shop, if present. Decisions are documented on the Direct Gas Consumption Preliminary Monitoring Requirements Worksheet (see Exhibit A.9).

When determining the required number of pulse-head meters, the field engineer and gas meter shop representative should consider the piping configuration in the building, the number of end uses served by gas, and whether or not sumchecks are required. Existing meters that may be replaced by meters with pulseheads should be distinguished from situations where new meters with pulseheads should be installed. The field engineer shall complete the Direct Gas Monitoring Requirements Worksheet as follows.

- **Meter ID** - Enter the ID number of the existing gas meter to be monitored.
- **Equipment description** - Describe the piece of equipment to be monitored.
- **Location** - Describe the proposed installation location for each pulse-head meter.

The completed worksheet will be used to help prepare a cost estimate for monitoring at the site and will help to determine the number of digital channels necessary to monitor the site.

In addition to completing this worksheet, the field engineer should mark each proposed meter location on the gas riser diagram to show its relationship to existing meters and equipment, and on the energy systems components sketch to show the physical location in the building.

If gas consumption is to be measured by proxies, then the appropriate proxy for each piece of equipment shall be selected.

A.5.14 Documenting ISS

At the conclusion of the ISS, leave the site and complete the necessary documentation by preparing a cost estimate for monitoring the site and then assembling an ISS submittal package.

A.5.14.1 Preparing Cost Estimate

Based on the information gathered during the ISS, prepare a cost estimate using the form contained in Exhibit A.10. This form documents cost estimates for completing a full site characteristics survey, developing a measurement plan, and installing monitoring equipment at the site.

For each phase, record labor expenses by labor category and hardware expenses by equipment type.

The second page of the form provides space for discussion of the estimated costs and any circumstances at the site that may affect the project schedule. High or low cost estimates should be justified. Also discuss any optional measurements that can be collected at the site and the associated costs.

A.5.14.2 Preparing ISS Submittal Package

The ISS submittal package is a collection of completed forms that document the ISS. File this package in the site notebook as the ISS record and submit to the program manager for approval. The following shall be included in the submittal package:

1. Initial Site Survey Checksheet (see Exhibit A.11)
2. Cover Page

- a. site identification
 - b. Initial Site Survey Submittal (see Exhibit A.12) - This form shall be completed by the field engineer. Enter the date, initials, and recommendation for the site (whether it should be accepted for further work, rejected, or requires a special exception of some kind). If the recommendation is for rejection or exception, include a Site Rejection Form.
- 3. Cost Estimate
 - 4. General Site Information Form
 - 5. General Building Information Form (primary)
 - 6. Meter/Account Map
 - 7. Operational/Installation Constraints Form
 - 8. Energy System Sketches
 - 9. Floor Plan Sketches for each floor in building
 - 10. Tenant Contact Information Form
 - 11. Riser Information Form for both electricity and gas, if present
 - 12. Preliminary Wattmeter Channel Requirements Summary
 - 13. Supplemental Pages (e.g., needed to support gas metering)
 - 14. General Building Information Form (secondary)
 - 15. Initial Site Survey Checksheet (completed)

SITE REJECTION FORM

SITE ID: _____ **Date:** _____ **Submitted by:** _____

Check appropriate box below:

<u>Rejecting Party</u>	☐	Owner	☐	Sponsor
	☐	Tenant	☐	PNL

<u>Rejection Reason</u>	☐	Privacy
	☐	Inconvenience
	☐	Legal liability
	☐	Safety
	☐	Aesthetics
	☐	Value
	☐	Inadequate documentation
	☐	Excessive panels/circuits
	☐	Manufacturing/Industrial
	☐	Cannot identify owner
	☐	Vacant building
	☐	Inappropriate business type
	☐	Inappropriate HVAC fuel type
	☐	Other concerns

For each item checked, please elaborate: _____

Approved: _____ **Date:** _____

WALK-BY BUILDING SURVEY FORM

Site ID: _____

Building No.: _____ of _____

Date: ____ / ____ / ____

Surveyor Initials: _____

County: _____

Map pg #: _____

Map grid #: _____

1. Problem Sites - If you cannot enumerate buildings at a site, explain why; e.g., site has been torn down or cannot locate site. Do not complete any other part of this form.
2. Building Addresses - If street addresses are visible, record the addresses using the following table. Record addresses for all sides of the building that have a public entrance.

Start No.	Ending No.	Direc. Prefix	Street Name	Direc. Suffix
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Record comments for buildings that have missing or incomplete addresses; e.g., "SE CORNER OF 2ND AND RIVERSIDE" or "2 MILES N OF SALT CREEK."

3. Number of above grade stories - Record maximum number of stories above lowest grade line. Include any ground floors that are partially below grade, but have at least 50% of their wall area above grade.
4. Building identifier - Record the building name, name of the largest tenant in the building, or any other name that will serve as a unique identifier for this building.
5. Number of businesses. Record the number of businesses that occupy the building. Record a zero if vacant. If you cannot determine the exact number, estimate.

Site ID: _____

Building No.: _____ of _____

- a. Building size - Check the range below that best approximates the area of the building in square feet.

_____ < 1000	_____ 30000-50000
_____ 1000-5000	_____ 50000-100000
_____ 5000-10000	_____ 100000-200000
_____ 10000-30000	_____ > 200000

- b. Primary and secondary business type - Use the following list when determining business type. An entry of OTH or UNK should be explained under Notes.

OFF = Office	OTH = Other
NFR = Nonfood Retail	NCM = Noncommercial
GRO = Grocery	UNK = Unknown
RES = Restaurant	NAP = Not Applicable
WAR = Warehouse	

- c. Primary business type - Identify the business type that best characterizes the economic activity of the businesses in the building and the approximate percentage of total floor area this business type occupies.

_____ type _____ %

- d. Secondary business type - Identify the business type that best characterizes the second most important economic activity of the businesses in the building and the approximate percentage of total floor area this business type occupies.

_____ type _____ %

- e. Primary Functional Use Type - Circle the functional use type of the entire building or the largest portion of the building's floor area.

STR = Storage	PBS = Public Service
OFF = Office	OTH = Other
FDP = Food Preparation	

Include comments that will be useful to help you remember the building, and any comments that may help determine the building's suitability as a monitoring site; i.e., approximate age, whether it has been remodeled, whether there are gas meters, extent of mixed use.

Site ID: _____

Building No.: _____ of _____

Site Sketch - Roughly sketch the site, showing each building that has been identified. Clearly label each building with its building number. Show orientation of the sketch (indicate North), and sketch and label adjoining streets if possible. Complete this item only for the Building No. 01 form.

GENERAL BUILDING INFORMATION FORM

Site ID _____ Building No. _____ Date _____ Initials _____

Physical description: _____

Floor area: _____ Number of above grade stories: _____

Number of tenants: _____

Business types: OFF NFR WAR GRO RES OTH

Total number of business types: _____

Common space? YES NO

Vacant space? YES NO

Primary business type: _____ Primary functional use: _____

Fuels by End Use:

Space Heat	ELEC	GAS	OTHER	NOT PRESENT	
Cooling	ELEC	GAS	OTHER	NOT PRESENT	
Lighting	ELEC			NOT PRESENT	
Data Processing	ELEC			NOT PRESENT	NA FOR BLDG TYPE
Refrigeration	ELEC	GAS	OTHER	NOT PRESENT	NA FOR BLDG TYPE
Food Preparation	ELEC	GAS	OTHER	NOT PRESENT	NA FOR BLDG TYPE

If OTHER is indicated, specify: _____

(If OTHER is indicated for SPACE HEAT, recommend for rejection)

Meter Numbers: Electric Gas

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

NOTES:

FLOOR AREA WORKSHEET

Site ID _____ Building No. _____ Date _____ Initials _____

Segment Area No.	Length (ft)	Width (ft)	Square Feet	Number of Stories	Circle (C) or Triangle (T)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Segment sketch:

Total area: _____

TENANT CONTACT INFORMATION FORM

Site ID _____ Building No. _____ Date _____ Initials _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____
Contact 2 - Name: _____
Title: _____
Phone: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____
Contact 2 - Name: _____
Title: _____
Phone: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____
Contact 2 - Name: _____
Title: _____
Phone: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____
Contact 2 - Name: _____
Title: _____
Phone: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____
Contact 2 - Name: _____
Title: _____
Phone: _____

Site ID _____ Building Number _____ Date _____ Initials _____

Tenant ID: _____
Business Type: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____

Contact 2 - Name: _____
Title: _____
Phone: _____

Tenant ID: _____
Business Type: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____

Contact 2 - Name: _____
Title: _____
Phone: _____

Tenant ID: _____
Business Type: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____

Contact 2 - Name: _____
Title: _____
Phone: _____

Tenant ID: _____
Business Type: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____

Contact 2 - Name: _____
Title: _____
Phone: _____

Tenant ID: _____
Business Type: _____

Firm Name: _____
Contact 1 - Name: _____
Title: _____
Phone: _____

Contact 2 - Name: _____
Title: _____
Phone: _____

2 of 2

OPERATIONAL/INSTALLATION CONSTRAINTS FORM

Site ID _____ Building Number _____ Date _____ Initials _____

Installation constraints: _____

End-use mixing: _____

Excessive crowding: _____

Schedule limitations: _____

Loads affected by power interruption:

COMPUTERS	ALARMS	TELEPHONE	TIMERS	HVAC	OTHER
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Special restart procedures: _____

Limited access areas: _____

Aesthetic sensitivities: _____

Other Factors: _____

Site ID _____ Building Number _____ Date _____ Initials _____

Floor Plan Sketch

Floor Number _____ of _____ Above grade _____ Below grade _____

RISER INFORMATION FORM

Site ID _____ Building Number _____ Date _____ Initials _____

Gas _____

Electric _____

Riser Diagram:

Date Issued:
September 1993

Supersedes Issue Dated:

Page
1 of 2

Mobile Energy Laboratory Procedure 5.0, Exhibit A.7
Electrical End-Use Metering, Version 1

Site ID _____ Building Number _____ Date _____ Initials _____ pg 2
Gas _____ Electric _____

Node Type	Node Name	Voltage Config.	Volts	Current Rating/KVA	Served From	Monitored?

PRELIMINARY WATTMETER CHANNEL REQUIREMENTS SUMMARY

Site ID _____ Building Number _____ Date _____ Initials _____

[illegible]

TOTAL

COMMENTS:

DIRECT GAS CONSUMPTION PRELIMINARY MONITORING REQUIREMENTS WORKSHEET

Site ID _____

Date: _____

Initials: _____

Meter ID

Equipment
Description

Location

Total Required

Comments:

Date Issued:
September 1993

Supersedes Issue Dated:

Page
1 of 1

Mobile Energy Laboratory Procedure 5.0, Exhibit A.9
Electrical End-Use Metering, Version 1

COST ESTIMATE

Site ID _____ Date _____ Initials _____

TASK	LABOR CATEGORY	RATE	HOURS		COST	
			EST.	ACTUAL	EST.	ACTUAL
AUDIT AND MEASUREMENT PLAN	PROJECT MANAGER	()	_____	_____	_____	_____
	LEAD ENGR	()	_____	_____	_____	_____
	ENGR ASST	()	_____	_____	_____	_____
	AUDITOR	()	_____	_____	_____	_____
	ELECTRICIAN	()	_____	_____	_____	_____
	_____	()	_____	_____	_____	_____
SUBTOTAL			_____	_____	_____	_____
INSTALLATION	PROJ MAN	()	_____	_____	_____	_____
	LEAD ENGR	()	_____	_____	_____	_____
	ENGR ASST	()	_____	_____	_____	_____
	AUDITOR	()	_____	_____	_____	_____
	ELECTRICIAN	()	_____	_____	_____	_____
	_____	()	_____	_____	_____	_____
SUBTOTAL			_____	_____	_____	_____
HARDWARE REQUIREMENTS						
ITEM			QUANTITY		COST	
			EST.	ACTUAL	EST.	ACTUAL
	()	()	_____	_____	_____	_____
	()	()	_____	_____	_____	_____
	()	()	_____	_____	_____	_____
	()	()	_____	_____	_____	_____
	()	()	_____	_____	_____	_____
	()	()	_____	_____	_____	_____
SUBTOTAL			_____	_____	_____	_____
TOTAL			_____	_____	_____	_____
TOTAL HARDWARE			_____	_____	_____	_____
GRAND TOTAL			_____	_____	_____	_____

Site ID _____ Date _____ Initials _____

Explanation of inordinate cost estimates: -

HVAC Measurements: _____

Gas Measurements: _____

Tenant Totals: _____

INITIAL SITE SURVEY CHECKSHEET

Site ID: _____

Date: _____

1. Cover Page	_____	_____
2. Site Rejection Form	_____	_____
3. Cost Estimate	_____	_____
4. General Site Information Form	_____	_____
5. General Building Information Form (primary)	_____	_____
6. Meter/Account Map	_____	_____
7. Operational/Installation Constraints Form	_____	_____
8. Energy Systems Sketches	_____	_____
9. Floor Plan Sketches	_____	_____
10. Tenant Contact Information Form	_____	_____
11. Riser Information Form	_____	_____
12. Preliminary Wattmeter Channel Requirements
Summary	_____	_____
13. General Building Information Form
(secondary)	_____	_____
14. Initial Site Survey Checklist (completed)	<u>Initials</u>	<u>NA</u>

INITIAL SITE SURVEY SUBMITTAL

Site ID _____

Primary Building _____

FIELD ENGINEER RECOMMENDATION:

____ Accept
____ Reject
____ Exception

If recommendation is for rejection, attach completed Site Rejection Form.

If recommendation is for exception, explain:

Date _____

Name _____

ACTION:

Reviewed by: _____

Date: _____

____ Approved
____ Reject
____ Hold for further work

COMMENTS:

Mobile Energy Laboratory

Procedure 6.0

Evaluating Illuminance Levels

6.0 Evaluating Illuminance Levels

6.1 Introduction

A common way to achieve energy conservation in facilities is by installing efficient lighting systems (either new or retrofit). For retrofit installations, the quantity of available light before and after such retrofits must be understood to determine the effectiveness and applicability of lighting system improvements. In most nonresidential facilities, lighting represents a significant share of the total energy consumption and an even larger share of the total electricity consumption. Efficient lighting systems are readily available to replace old, outdated and inefficient systems. The measurement of lighting levels in facilities is a critical Mobile Energy Laboratory (MEL) capability.

6.2 Scope

This procedure defines a testing methodology to be used in evaluating illuminance levels in facilities. This test method will determine the quantity of light being delivered to a working surface within a facility work space and compare the measured quantity to an established required quantity.

6.3 Referenced Documents

Illuminating Engineering Society of North America (IES). 1984. *IES Lighting Handbook, 1984 Reference Volume*. New York.

Illuminating Engineering Society of North America (IES). 1987. *IES Lighting Handbook, 1987 Application Volume*. New York.

Illuminating Engineering Society of North America (IES). 1989. *IES Lighting Ready Reference*. New York.

6.4 Terminology

When describing lighting systems, extensive use of special terms and definitions is required. A dictionary of lighting terminology is found in the *IES Lighting Ready Reference* (IES 1989) and *IES Lighting Handbook* (IES 1984). Some of the key terms and phrases include:

- electric lighting power - the actual or rated input power of an electric luminaire
- illuminance - the IES spectrum-weighted light flux received by a surface from all directions
- luminaire - any light source; in the context of this procedure, an electric light fixture
- Efficacy - the ratio of the total luminous flux to the total radiant flux, expressed in lumens per watt.

- photometer - a transducer that responds to light in particular wavelengths.
- coefficient of utilization (CU) - the ratio of the luminous flux from a luminaire as received on the work plane to luminous flux emitted by the luminaire's lamps above.

6.5 Summary of Procedure

The flowchart shown in Figure 6.1 provides a representation of the key activities required to complete the measurement and evaluation of illuminance levels in a facility work space.

Figure 6.1. Flowchart of the Activities for Evaluating Illuminance Levels

6.6 Significance and Use

When evaluating a facility's actual lighting system, the quantity of light in a particular working environment must be measured or surveyed. The results of these surveys may be used

- alone or with other surveys for comparison purposes
- to determine compliance with specifications
- to reveal the need for maintenance, modification, or replacement.

The adequacy of a lighting system to provide a space with required illumination is determined by the quantity and quality of the supplied light. This test procedure provides only a determination of the quantity of light, and not a measurement of the quality of delivered light. If the measured light values fall within accepted ranges, but the illumination in the space is inadequate for the required tasks, then problems with lighting quality probably exist. A professional lighting designer should be involved in such cases to assist in determining the nature of the lighting quality deficiency.

6.7 Apparatus

Illuminance shall be measured with an RCC/340 Illuminometer or other equivalent equipment.^(a)

Lighting supply voltages shall be measured with appropriate digital multimeter.

The photometer shall have a clean sensing element and be at a stable temperature prior to, and during, each test. Prior to each test run, the photometer shall be zeroed.

6.8 Hazards

Lighting fixtures are usually located in elevated locations that are difficult to reach. Gathering information about fixtures requires the use of ladders, scaffolds, or other devices used to elevate individuals. Lights are thermally hot and usually electrically powered. Care and precaution shall be exercised by all individuals involved in the lighting assessment to prevent falls, burns, and electric shock.

6.9 Calibration and Standardization

The photometers and other equipment that are used for measuring work space illuminance shall have manufacturers' specified maintenance and calibration requirements. All equipment shall be kept in good working condition and calibrated periodically.

- (a) References to specific manufacturers and models are not to be construed as an endorsement as compared to equivalent instrumentation available from other manufacturers.

Maintenance and calibration records of test equipment shall be maintained as part of the MEL project files.

6.10 Procedure

The MEL procedure for measuring lighting levels is based on the IES Interior Lighting Survey Procedure (IES 1984). This document should be used as the actual field procedure. A brief overview of this procedure is presented below.

6.10.1 Conditioning Lighting Systems

6.10.1.1 Burn-in

Several types of lights have significant variations in their light output during the initial burn-in period. Lighting systems should be operated for a minimum of 100 hours prior to testing.

6.10.1.2 Warm-Up

Gas discharge lights require approximately 1 hour to reach stable operating condition from a cold startup. These systems should be operated continuously for 1 hour prior to testing to ensure that a stable operating condition has been achieved.

6.10.1.3 Photometer Stabilization

Before readings are taken, expose the photometer to the approximate illuminance to be measured until it becomes stabilized.

6.10.2 Determining Space Type

The IES Interior Lighting Survey Procedure (IES 1984) identifies separate sensor location methodologies, depending on the space configuration. The appropriate space configuration for the space to be tested should be determined using the space types as criteria. If necessary, the total space should be divided into separate spaces to fit the IES criteria, which requires a working sketch of the space.

6.10.3 Determining Luminaire Configuration

The IES Interior Lighting Survey Procedure (IES 1984) also identifies specific luminaire configurations for spaces and recommends sensor location as a combination of space type and luminaire configuration. The appropriate space configuration for the IES procedure (IES 1984) should be determined based on the combination of space type and luminaire configuration. Prepare a final sketch of the space using the results of the space configuration.

6.10.4 Identifying Measurement Points

Apply the IES procedure criteria to each individual space so that each measurement point on the final sketch of the space can be located. The IES procedures (IES 1984) for average illuminance measurements may not entirely apply to occupied buildings for one or more of the following reasons:

- light fixture arrangement does not follow a regular plan
- furniture and office equipment prevents taking measurements on the standard IES grid
- presence of furniture results in irregular shading of work surfaces.

Under these conditions, take measurements on each work surface, one at the center and one on the periphery of the visual task area.

6.10.5 Conducting Illuminance Measurements

Measure and record the illuminance for each point identified in the final sketch of the space with the photometer located 760 mm (30 in.) from the floor in a horizontal position. The measurements should be performed during the time of day that the space is normally occupied. Daytime surveys should be made with the shades adjusted for best control of daylight. In spaces used 24 hours per day with available daylight, testing should be duplicated during daylight hours and at night.

6.10.6 Collecting Data

Determine the rated electric lighting input power for all luminaries in each of the spaces being surveyed.

6.11 Calculation or Interpretation of Results

6.11.1 Average Illuminance

Calculate the average illuminance in each space based on the IES procedure (IES 1984) and the measured illuminance values.

6.11.2 Input Power Density

Calculate the rated lighting input power density (LIPD) (watts per square meter) for each area surveyed, and/or the entire building, using the rated power, not the actual input power.

6.11.3 Efficacy*CU

Calculate the Efficacy*CU product, which is the ratio of the average illuminance to LIPD. LIPD is a measure of the overall efficiency of a lighting system that includes the effects of luminaire and work surface condition and placement, shading by obstructions, and the reflectivities of floor, ceiling, walls, furniture, and other room contents. In field testing, a value of the Efficacy*CU product can be inferred from average measured illuminance and measured or rated lighting input power, but it is generally not feasible to factor out efficacy and CU as separate values.

6.12 Report

Prepare a brief written report for each space where a lighting measurement test has been performed. This test shall include a diagram of the space's light level measurement points and a tabular listing of measured values and calculated average illumination levels. The calculated power density and Efficacy*CU product shall be included in this table. In addition, prepare a summary report that details the general findings and conclusions. This report may include a comparison with IES recommended illumination levels (IES 1987) for similar spaces or recommendations for further testing to determine the appropriateness of the lighting system for the space.

6.13 Precision and Bias

The method outlined in the IES procedure (IES 1984) should provide results within 10% of the values that would be obtained by dividing the space into 0.6-m (2-ft) squares, taking illuminance measurements in each of these squares, and averaging the readings.

Portable photometers, which are used in field measurements of lighting quantity, have limited accuracy resulting in uncertainty or lack of precision in actual measurements. Most photometers are sensitive to radiation beyond the visible spectrum that would bias the measurement unless they are corrected by the addition of appropriate filters that ensure readings reflect only visible light. Light striking a photometer at a low angle of incidence is reflected instead of measured. The degree of reflection is a function of the cosine angle of the incident light. Measurement photometers must have cosine correction to correct this reflection phenomenon.

6.14 Annexes and Appendixes

6.14.1 Annexes

CU	coefficient of utilization
IES	Illuminating Engineering Society of North America
LIPD	lighting input power density
MEL	Mobile Energy Laboratory

6.14.2 Appendixes

Appendix A contains the Lighting Survey Data Sheet.

6.15 Personnel Support

Lighting design is a specialized field that requires training, skill, and experience for success. Individuals involved in the measurement of lighting quantity should have a general understanding of the issues and principles of lighting design.

6.15.1 MEL Staff

One MEL field technician with field experience and familiarity with lighting system testing is sufficient to perform the light level measurement test.

6.15.2 Facility Staff

An individual from a federal facility, who is familiar with the facility to be tested, is required during the initial stages of the evaluation of illuminance levels to ensure that there is appropriate interface with facility occupants and that the MEL staff are aware of the lighting controls.

6.15.3 Notes

The IES handbooks (IES 1984, 1987) provide valuable information that should be reviewed by any individual involved in testing any aspect of a lighting system. The information provided in these handbooks ranges from particular information about specific types of lighting systems to general background information on how humans see. The Application Volume (IES 1987) provides guidance on lighting requirements for a wide range of space types. Any lighting system assessment must include the IES handbooks (IES 1984, 1987) as ready references.

6.16 Testing Schedule

The lighting level measurements and report preparation for a typical tested facility can be completed for each space tested in an 8-hour day.

Appendix A

Lighting Survey Data Sheet

Attach reflected ceiling plan, work station plan, illuminance raw data and utility rate schedule. Be sure to indicate switch and panel locations, window locations, and light fixture and work surface type on the plans. Use separate data sheets for each area with distinctive lighting or use characteristics.

Site: _____ Bldg: _____

Date: _____ Time: _____ Prepared by: _____

Measured lighting circuit voltages: ϕ A: _____ V ϕ B: _____ V ϕ C: _____ V

Room#: _____ Area: _____ sf #Occ: _____ MaxOcc: _____

Function: _____

Light Fixtures

Type 1. Location: _____ Panel: _____ ϕ : _____ Sw.Ckt: _____

Luminaire Qty: _____ Type: _____ Power: _____

Ballast Qty: _____ Type: _____ Power: _____

Bulb/tube Qty: _____ Type: _____ Power: _____

Type 2. Location: _____ Panel: _____ ϕ : _____ Sw.Ckt: _____

Luminaire Qty: _____ Type: _____ Power: _____

Ballast Qty: _____ Type: _____ Power: _____

Bulb/tube Qty: _____ Type: _____ Power: _____

Type 3. Location: _____ Panel: _____ ϕ : _____ Sw.Ckt: _____

Luminaire Qty: _____ Type: _____ Power: _____

Ballast Qty: _____ Type: _____ Power: _____

Bulb/tube Qty: _____ Type: _____ Power: _____

Type 4. Location: _____ Panel: _____ ϕ : _____ Sw.Ckt: _____

Luminaire Qty: _____ Type: _____ Power: _____

Ballast Qty: _____ Type: _____ Power: _____

Bulb/tube Qty: _____ Type: _____ Power: _____

Work Surfaces

1. Ht.AFF: _____ ft Color: _____ Rflvty: _____ Finish: _____

2. Ht.AFF: _____ ft Color: _____ Rflvty: _____ Finish: _____

3. Ht.AFF: _____ ft Color: _____ Rflvty: _____ Finish: _____

4. Ht.AFF: _____ ft Color: _____ Rflvty: _____ Finish: _____

Ceiling. Type: _____ Ht.AFF: _____ ft Color: _____ Rflvty: _____

Floor. Color: _____ Rflvty: _____ Wall. Color: _____ Rflvty: _____

Mobile Energy Laboratory

Procedure 7.0

Steam Distribution System Evaluation

7.0 Steam Distribution System Evaluation

7.1 Introduction

Facilities with centralized boiler plants and dispersed buildings, or process loads that use a central steam source, require steam distribution systems (SDS). These SDSs have typically been modified over time and may not be well understood. Significant opportunities for energy savings may be available by identifying and correcting SDS problems. Routine maintenance of the SDS may have been neglected so that replacement is the best alternative; operational practices may be responsible for large inefficiencies; or loads may be better served by a source other than the central plant and distribution system. A better understanding of the SDS is always required for meaningful evaluation.

7.2 Scope

The SDS evaluation procedure defines guidelines for the examination, problem identification, and evaluation of a facility steam or hot water distribution system. This procedure is limited to the distribution components located on the exterior of a boiler house and consuming buildings. SDS problems may be identified by facility operators prior to, or as a result of, the preparation of a Mobile Energy Laboratory (MEL) Assignment Plan (MAP), which identifies testing to be undertaken at a specific site.

7.3 Terminology

"Steam distribution" used in this procedure represents steam or hot water distribution.

7.4 Summary of Procedure

Figure 7.1 provides a flowchart of the activities required to conduct an SDS evaluation. Some evaluations will not require completion of all steps because of intermediate findings that provide adequate guidance on the required corrective actions or indicate that subsequent steps are beyond budgetary allowances.

7.5 Significance and Use

SDS evaluations have been developed for use by trained and experienced MEL teams for application in field tests of SDSs. SDS evaluations are not intended to be sufficient for complete field testing.

7.6 Apparatus

SDS evaluations require a standard set of hand tools and electrical measuring equipment, as well as a range of temperature and pressure sensing devices. Noncontact temperature measurement devices that are capable of measuring a distance of at least 10 ft are desirable.

Figure 7.1. Flowchart of Key Steam Distribution System Evaluation Activities

Every SDS evaluation shall require steam flow measurements, which can be expedited if multiple flowmeters are available for simultaneous application. Each flowmeter requires a range of insertion turbines to accommodate the range of possible flows. Application of a steam flowmeter requires the use of special, expendable valve assemblies for the insertion turbines. A portable computer for data collection, analysis, and report preparation shall be required.

Infrared scans require appropriate infrared cameras that shall be obtained through sources other than the MEL.

7.7 Hazards

All field activities present a potential for personal injury to personnel. The SDS testing procedure subjects personnel to a risk of burns from steam. Field personnel shall exercise extreme caution at all times to ensure that the danger of burns is minimized.

7.8 Calibration and Standardization

All test equipment shall have specific maintenance and calibration requirements as specified under MEL Procedure 3.0, Equipment Inventory, Repair, and Accountability Guidelines.

Maintenance and calibration records for the test equipment shall be maintained as part of the MEL project files.

7.9 Procedure

Some of the specific tests performed for an SDS evaluation are dependent on preceding steps for identification and preliminary inputs. Other specific tests may be required because findings are different than the expected results of preliminary tests. The intent of this evaluation is not to just look for energy efficiency opportunities, but to provide a "global" view of the SDS.

7.9.1 Collecting Background Information

The Background Information form (see Appendix A) is a data collection form that shall be used in an SDS evaluation to ensure that appropriate questions are asked and brief answers recorded. Complete the Problem Survey form (see Appendix B) as background information is collected for an SDS. Use this form to identify a matrix of possible SDS problems and a brief identification of their existence, prior treatment, and possible follow-up action items.

7.9.1.1 Identifying and Contacting Site Contacts

Conditions at each facility are unique and significant efforts may be necessary to gather and understand required information. During MAP preparation, identify and contact appropriate facility energy representatives to assist with the SDS evaluation. Obtain facility utility bills, which may be subjected to analysis. Discussions with facility energy representatives may reveal the existence of specific problems with an SDS.

7.9.1.2 Developing Distribution System Plan

Obtain or develop a facility SDS plan and equipment list. This plan is usually available from the facility, but if not, develop a simple one-line diagram of the system to explicitly identify where problems may be occurring and to avoid communication uncertainties. The distribution diagram should identify all

- steam generators at the facility
- points of interconnection
- points of existing metering
- major distribution lines, pumping stations, and pressure reducing stations
- steam lines and condensate return lines
- pipe sizes and lengths

- significant process loads
- larger buildings
- steam traps.

Diagrams and equipment lists should be refined into a set of as-built drawings for continued use by the facility energy management staff.

7.9.1.3 Obtaining Distribution System Modification History

A brief history of the SDS should be obtained, if available, to help identify what kinds of major modifications have been made and when they occurred to gain a perspective on the age of the system and degree of change at the facility. Several components of an SDS are subject to corrosion that is essentially time dependent, so the age of each component of the system is a critical variable.

7.9.1.4 Identifying Distribution System Problems

Using the distribution diagram, discuss the following specific questions about historical SDS problems with the site representative:

- the kinds of problems that are occurring
- where (in the SDS) the problems are occurring
- when these problems occur (day of week, time of day, and time of year)
- the last time a problem occurred
- the availability of system performance records containing specific information
- the kinds of corrective actions that have been taken to alleviate the problems.

7.9.1.5 Obtaining Distribution System Modifications

Obtain the general level of facility activity in the past, present, and future. If plans have been made to close a large section of the facility, do not perform detailed evaluations of that section. A section with no current problems and significant planned growth should receive careful evaluation to ensure adequacy.

7.9.1.6 Performing Distribution System Water Analysis

Because several possible system problems can involve corrosion, perform a complete analysis of the SDS's water quality. If the facility routinely performs these analyses, then the most recent report can provide background information. If these analyses are not available, an independent

outside testing service should perform a water quality analysis. This analysis should at least test conductivity, pH, hardness (total suspended solids should be calculated based on the hardness), and saturated gases, as well as investigate for the presence of corrosion products, balancing additives, and system treatment chemicals. An assessment of the condition of galvanic corrosion protection systems should also be included in the analysis if they exist. Water quality testing should be conducted at all endpoints and midpoints of each distribution leg, the boiler plant, and on all users of the system.

7.9.1.7 Locating Heat Loss

Problems with SDSs often involve excessive heat losses associated with degraded insulation, leaks, and poor installations. A large amount of information concerning the thermal characteristics of the system may be quickly collected by performing an infrared scan of the system from the ground, or possibly from an aerial survey. Survey results require significant analysis and follow-up, but may be an excellent way to locate large sources of heat loss.

7.9.1.8 Locating Water Loss

To identify leakage in the SDS, examine the amount of new make-up water required as it relates to known condensate, blowdown, and soot blower losses. Make-up in excess of known losses relates to steam or water losses in the system. If large losses are evident, then further work should be performed to identify the source of the loss. This loss may be inside specific buildings. If make-up water records are available, they should be examined to determine if losses are significant. If no records exist, collect losses for a period of several days, as well as blowdown and soot blower data. The entire condensate system should then be traced to identify and quantify condensate losses. The information obtained should quantify the losses and determine if further evaluation, such as measurement of condensate flows at various points, is necessary to locate the source of the additional losses.

7.9.2 Identifying Preliminary Problems

Based on information obtained in the Problem Survey and from discussions with facility representatives, identify a preliminary listing of SDS problems. For each identified problem, complete a Problem Identification form (see Appendix C), which is used to document a specific problem and provide a starting point for evaluating the problem.

7.9.3 Inspecting Steam Distribution System

After potential problems are identified and initial identification forms completed, conduct a visual examination/inspection of the SDS. During this inspection, examine each problem further and enter appropriate information on the Problem Identification form. The MEL team shall also look for unidentified problems and document them when they are located. Direct and remote temperature sensing devices are valuable during this inspection to help identify and confirm points of significant heat loss. Identify specific locations for sensor placement for each of the proposed tests.

7.9.4 Measuring Steam Flow

The measurement of steam flows at key points in the SDS can identify the relative size of various loads and system flows at specific points. Capacity problems can be immediately inferred from these tests. Measurements at both ends of a distribution reveal losses in the line. These measurements can be either short term (1 to 3 days repeated seasonally) or long term (6 to 12 months).

Most short-term measurements involve the measurement of steam flows at various points in the SDS. This one-time, short-period flow measurement provides an indication of the general system condition, but may not represent annual consumption and problems related to peak loads. These issues are revealed by measuring flows during periods of extreme system conditions. To obtain the measurement of a seasonally dependent load variation, collect flow information at the same points during peak and/or minimal periods. This activity is facilitated by the abandonment of the special valves necessary for the installation of the turbine flow meters.

Seasonal load variation can also be documented by leaving a few key flow recorders installed and routing the information to a data logger to collect a time series of data spanning the periods of seasonal variation. Budgets and the nature of the issues to be examined shall determine which method is preferable. Time series records tend to provide more accurate evaluations, but one-time tests are less expensive.

7.10 Report

Prepare a complete and concise report for each part of the SDS that is evaluated. This report shall identify the problem, evaluation tests performed, and results of specific measurements. Submit the background information and one-line diagrams to the facility representative.

7.11 Annexes and Appendixes

7.11.1 Annexes

MAP	MEL Application Plan
MEL	Mobile Energy Laboratory
SDS	steam distribution system

7.11.2 Appendixes

The form used to collect background information for an SDS is contained in Appendix A.

Appendix B contains the Problem Survey form, which is used to help identify SDS problems.

Appendix C contains the Problem Identification form, which is used to document a specific problem and provide a starting point for evaluation of the problem.

7.12 Personnel Support

SDS evaluations require that the MEL team include individuals familiar with the installation and operation of steam flow measurement equipment and testing procedures. These individuals shall also have working knowledge of the various types of SDSs that will be encountered at the federal facilities to be evaluated.

Identify an individual from the federal facility, who is familiar with the facility's SDS, to work closely with the MEL team. This individual must be available full time during the testing period.

7.13 Testing Schedule

The time necessary to complete the evaluation of an SDS depends on the complexity, condition, and size of the system, as well as the existence of adequate background information. A typical medium-size facility with some SDS information available should take approximately three days to complete the background information report, preliminary problem identification, and system tour. Each individual test should take one day for preparation and an average of two days to perform. Each tap should require eight hours for installation by a facility technician.

Appendix A

Steam Distribution System Evaluation Background Information

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

Steam Distribution Plans: Obtained _____ Produced _____

Steam Distribution Records: Obtained _____ Not Available _____

Number of Boiler Plants: _____

Boiler Plant Fuel(s): _____

Size of Boiler Plants: _____

Major Process Loads: _____

Major Buildings Supplied: _____

Use of Steam Outside Facility: _____

Facility Activity Levels:

Past: _____

Present: _____

Future: _____

Previous Testing Accomplished: _____

Water Analysis Testing: Obtained _____ Not Available _____

Appendix B

Steam Distribution System Evaluation Problem Survey

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

PROBLEM	Prior Exists	Needs Work Testing		Comments
Consumption	_____	_____	_____	_____
Under Capacity	_____	_____	_____	_____
Over Capacity	_____	_____	_____	_____
Age	_____	_____	_____	_____
Efficiency	_____	_____	_____	_____
Leakage	_____	_____	_____	_____
Steam Quality	_____	_____	_____	_____
Water Purity	_____	_____	_____	_____
Dirt	_____	_____	_____	_____
Water Slugging	_____	_____	_____	_____
Pressure	_____	_____	_____	_____
Control	_____	_____	_____	_____
Corrosion	_____	_____	_____	_____
Traps	_____	_____	_____	_____
Condensate	_____	_____	_____	_____
Other	_____	_____	_____	_____
Other	_____	_____	_____	_____

Comments:

Appendix C

Steam Distribution System Evaluation Problem Identification

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

Problem Description: _____

Location of Problem: _____

Timing of Problem:

Season: _____

Day of Week: _____

Hour of Day: _____

Last Occurrence: _____

Records (Documentation) of Problem History Available: _____

Corrective Actions Attempted: _____

Specific Testing/Measurements Required: _____

Comments From Field Examination of Problem: _____

Proposed Sensor Locations: _____

Date Issued:
September 1993

Supersedes Issue Dated:
July 1988

Page
C.1

Mobile Energy Laboratory Procedure 7.0, Appendix C
Steam Distribution System Evaluation, Version 2

Mobile Energy Laboratory

Procedure 8.0

Electrical Distribution System Evaluation

8.0 Electrical Distribution System Evaluation

8.1 Introduction

Federal facilities typically have a combination of centralized on-site electrical power generation and electrical power that is produced outside the facility by a local/regional utility (supplier), which is delivered to the facility via a high voltage line(s) and distributed throughout the facility via a distribution system. This electrical distribution system (EDS) has probably undergone a series of modifications since its initial design and installation that may have adversely affected its operating efficiency.

8.2 Scope

This procedure is a standard reference document to be used by Mobile Energy Laboratory (MEL) field specialists while performing an EDS evaluation, and is intended to serve as a basic guideline for all activities that are required to complete an EDS evaluation. In this procedure, the evaluation is limited to the EDS components within a facility between the supplier's point of delivery (usually a substation) and the endpoint of delivery (usually a process or building), or between the on-site generating station and the endpoint of delivery within the facility. Procedures for electrical end-use metering for a particular building are described in MEL Procedure 5.0.

The purpose of this testing is to collect and analyze information required to complete a comprehensive EDS evaluation, and to identify specific problems if necessary.

A detailed discussion of the types of background information to be obtained and a general description of field monitoring and/or special studies to be conducted are contained in this procedure. The extent of field monitoring is dependent on review of background information and the nature of the identified EDS problems.

8.3 Terminology

There are no terms in this procedure that require new or other than dictionary definitions.

8.4 Summary of Procedure

The flowchart shown in Figure 8.1 is a diagram of the sequence of key activities necessary to complete an EDS evaluation. At each step in the process, it may be desirable to backup one or two steps to obtain new or additional information before continuing to the next step.

Figure 8.1. Flowchart of Key Electrical Distribution System Evaluation Activities

8.5 Significance and Use

The test procedure is designed to evaluate the condition of an existing EDS. The findings may then be used to identify improvements in the EDS performance through operations and maintenance activities and equipment retrofits to achieve maximum system energy efficiency.

8.6 Apparatus

Specific instrumentation required to complete the type of testing expected to be encountered in the first phase of the EDS evaluation includes a standard hand tool kit, an electrical multimeter, and a portable line monitoring system capable of at least monitoring circuit voltage, current, and phase angle. A portable computer may also be needed for data collection, analysis, and report preparation.

8.7 Hazards

On-site activities present a potential for personal injury to personnel. Prudent safety precautions shall be taken at all times. Obtain and use (wear) whatever safety equipment is required, such as seat belts, safety glasses, hard hats, and hearing protectors.

8.8 Calibration and Standardization

Some of the equipment and sensors used during the EDS evaluation require routine maintenance and calibration as specified by the manufacturer. All equipment shall be maintained in good working condition and calibrated periodically.

Maintenance and calibration records for the test equipment shall be maintained as part of the MEL project files.

8.9 Procedure

The evaluation of the EDS shall be completed in two phases. Phase 1, which is completed during the initial site visit and MEL Application Plan (MAP) preparation, is a general troubleshooting and failure investigation, primarily using already existing information and/or data. Limited low-level field data collection may be done to supplement the available data. Phase 2 is a more thorough investigation into the nature and cause of the identified problem(s) requiring on-site data collection. Phase 2 shall occur at a later date, depending upon initial field investigation results and the nature of the tests to be conducted. Based on the results of Phase 2, a suspected EDS problem(s) may be classified as a power quality problem, power reliability problem, or an unexplained excessive energy consumption (or loss).

The various activities required to collect the information needed to perform an EDS evaluation are presented in Paragraphs 8.9.1 and 8.9.3. Each activity is discussed in detail with specific requirements identified and procedures described.

8.9.1 Phase 1: Collecting Background Information

Phase 1 of the EDS evaluation requires a thorough review of existing information about the EDS's performance. In particular, discussions with facility energy representatives may reveal that specific problems with the EDS are known to exist.

8.9.1.1 Identifying and Contacting Site Contacts

Conditions at each facility are unique and significant effort may be necessary to gather the basic information required to characterize the EDS and identify system problems. System problems may be identified by one of the following:

- the facility operators prior to preparation of the MAP
- as a result of conducting a MAP
- from more extensive on-site testing.

During MAP preparation, identify and contact appropriate facility energy representatives to assist with the EDS evaluation. Obtain facility utility bills which may be subjected to analysis.

8.9.1.2 Developing Distribution System Plan

Obtain or develop an EDS plan of the facility. This plan is usually available at the facility, but if not, develop a simple one-line diagram of the EDS to explicitly identify where the problems may be occurring and to avoid communication uncertainties. The distribution diagram should identify all

- utility delivery points and the location of existing metering
- major substations, distribution lines, and transformers
- significant process loads
- larger buildings.

8.9.1.3 Obtaining Distribution System Modification History

A brief history of the EDS should be obtained, if available, to help identify what kinds of major modifications have been made and when they occurred to gain a perspective on the age of the system and degree of change at the facility.

8.9.1.4 Obtaining Distribution System Maintenance History

To fully understand potential problem areas of the EDS, obtain a complete maintenance record. If detailed records are not available, attempt to reconstruct recent maintenance activities. This maintenance record enables the MEL team to identify potential areas of concern.

8.9.1.5 Identifying Distribution System Problems

Using the distribution diagram, discuss the following specific questions about historical chronic EDS problems with the site representative:

- the kinds of problems that are occurring
- where (in the EDS) the problems are occurring
- when these problems occur (day of week, time of day, and time of year)
- the last time a problem occurred
- the availability of system performance records containing specific information
- the kind of corrective actions that have been taken to alleviate the problems
- the facility representative's recommendations.

8.9.1.6 Obtaining Distribution System Modifications

Obtain the general level of facility activity in the past, present, and future. If plans have been made to close a large section of the facility, do not perform detailed evaluations of that section. A section with no current problems and significant planned growth should receive careful evaluation to ensure adequacy.

Use the EDS evaluation Background Information form (see Appendix A) to ensure that appropriate information is obtained and results are recorded. Retain completed forms in the site file.

8.9.2 Preliminary Problem Identification

After the background information is reviewed, it may be possible to identify chronic problem areas within the EDS. For each identified problem, complete a Problem Identification form (see Appendix B), which is used to document a specific problem and provide a starting point for evaluating the problem. Target suspected problem areas for follow-up detailed testing for peak loading or peak demand, low power factor, consumption, capacity, age, efficiency, and phase balance.

8.9.3 Phase 2: Recommending Special Field Testing

Based on specific problem areas identified from Phase 1, make recommendations for further investigations into one or more of the following specific study types. These studies should provide more definitive results and pinpoint the exact cause of the system problem.

- **High Priority**
 - harmonic analysis
 - load flow studies
 - power reliability studies
 - short-term substation metering
 - special (power quality) monitoring
 - specific point monitoring (i.e. transformers, buildings, process devices)
 - system grounding
 - power regulation
- **Low Priority**
 - power factor correction studies
 - peak load shaving studies
 - surge protection studies
 - projected future demands

8.9.3.1 Short-Term Metering

Most testing will be a one-time or short-duration measurement (2 to 5 days) taken when the MEL team is assigned to the facility. While this measurement provides an indication of the general condition of the system, it may not exhibit conditions that produce problems related to annual consumption or peak loads. For problems that are seasonally dependent, it may be necessary to return to the facility during a period when the problem is expected to occur.

8.9.3.2 Long-Term Metering

Depending on the type of testing being performed, a viable option is to install the necessary metering equipment on a long term basis and collect data for an extended period of time (up to 12 months). Long-term tests require the installation of data logging equipment and a communication link between the data logger and the MEL data acquisition system. The time series data collected during long-term metering tend to provide more accurate evaluations, but short-term test are less expensive.

8.10 Report

Prepare a complete and concise report for each part of the EDS that is evaluated. This report shall identify the problem, evaluation tests performed, and the results of specific measurements. Submit the background information and one-line diagrams to the facility representative.

8.11 Annexes and Appendixes

8.11.1 Annexes

EDS	electrical distribution system
MAP	MEL Application Plan
MEL	Mobile Energy Laboratory

8.11.2 Appendixes

The form used to collect background information for an EDS is contained in Appendix A.

Appendix B contains the Problem Identification form, which is used to help identify EDS problems.

8.12 Personnel Support

To successfully obtain required information and complete the planned testing, support and cooperation from various site personal is necessary. Assistance is required from at least one individual who is thoroughly familiar with the EDS and its history of problem(s). The assistance of a qualified electrician, who is familiar with the electrical system and has access to all equipment, is required during some of the testing.

Appendix A

Electrical Distribution System Evaluation Background Information

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

Electrical Distribution Plans Available: obtained _____ produced _____

Electrical Distribution System Records: obtained _____ not available _____

Facility Future Plans: _____

Number and Capacity of On-site Generation: _____

Number and Size of Incoming Distribution Lines: _____

Number and Location of Substations: _____

Major Building Supplied: _____

Major Process Loads: _____

Appendix B

Electrical Distribution System Evaluation Problem Identification

Date: _____ Completed by: _____

Site ID: _____

Working Contact: _____ Phone: _____

Problem Description: _____

Location of Problem: _____

Occurrence of Problem: _____

Season _____

Day of Week _____

Hour of Day _____

Last Occurrence _____

Existing Documentation of Problem Available: yes _____ no _____

Corrective Actions Attempted: yes _____ no _____

If yes, describe: _____

Specific Additional Testing/Measurements Required: _____

Comments: _____

Mobile Energy Laboratory

Procedure 9.0

Boiler System Efficiency Evaluation

9.0 Boiler System Efficiency Evaluation

9.1 Introduction

One of the major energy consuming systems at most facilities and/or large buildings is a steam or hot water generator. These systems convert large amounts of energy into steam or heated fluids for direct end-use application. All evaluations of the cost effectiveness of any retrofit measure that has direct or indirect impacts on these end uses require that the conversion efficiency of the boiler be determined.

The kind and level of detail of boiler system efficiency data, as well as the expected results, will have been identified as part of the assessment that recommended that a boiler system efficiency evaluation (BSEE) be conducted. This entails the creation of a detailed test plan for the expected activities, including the analysis procedures.

9.2 Scope

This procedure provides basic guidelines for conducting BSEE as part of a general testing program. It is assumed that the rationale and reasons for the BSEEs has been well developed and identified as part of a general facility energy assessment and Mobile Energy Laboratory (MEL) Application Plan (MAP). A range of possible protocols for BSEEs may be applied, depending on the evaluation objectives, but the objective of the effort must always be established prior to initiation of testing.

The American Society of Mechanical Engineers (ASME) Performance Test Code for Steam Generating Units (ASME 1974) shall be followed, which provides complete instructions for testing steam generating units to determine efficiency, capacity, and other related operating characteristics. However, this test code is intended as a generic guide for conducting performance testing on a variety of steam generating units. A competent engineer must evaluate each unit to be tested and develop a specific test protocol that meets the accuracy and intention of the ASME test code (ASME 1974). Additional ASME Power Test Codes providing detailed specifications for apparatus and procedures involved in the testing of steam-generating units are listed in Section 3.13 (ASME 1974). The code also includes worksheets and reporting forms.

9.3 Referenced Documents

American Society of Mechanical Engineers (ASME). 1974. *Power Test Code Steam Generating Units*. PTC 4.1-1974, New York.

9.4 Terminology

The terms "boiler" and "steam" are used in this procedure to include a range of conversion devices and working fluids.

The efficiency of steam generating equipment as determined by this procedure is the gross efficiency, where gross efficiency is the ratio of heat absorbed by the working fluid(s) to the heat input. Equivalent heat in the power required by the auxiliary equipment external to the boiler envelop is disregarded.

9.5 Summary of Procedure

The flowchart shown in Figure 9.1 is a simplified expression of the activities required to complete a BSEE.

Figure 9.1. Flowchart of Boiler System Efficiency Evaluation Activities

9.6 Significance and Use

All boilers include nominal sets of instrumentation for monitoring ongoing operations, but efficiency tests are usually performed during startup testing. Most of a boiler's installed instrumentation is of unknown accuracy because of the lack of current calibration in operating plants.

Performing an efficiency test provides a set of efficiency data and checks the set of installed boiler instruments. Accepted efficiency testing procedures require that a boiler operate as designed and be reasonably clean; thus, the boiler is tuned to operate as well as it is capable. This tune-up may pay for the costs associated with the efficiency testing procedure, resulting in fuel cost reductions.

This MEL test procedure is limited to the conversion efficiency of the boiler itself and does not include the efficiency of distribution systems or devices that convert the steam into some other form of energy, such as hot water or electricity.

9.7 Apparatus

Boiler system efficiency testing requires working boiler instruments and gauges, as well as a specific set of special tools to assist in confirming proper operation. The steam flow measurement devices installed on the boiler are usually not adequate. Special fittings and insertion turbines designed to operate with steam flow recorders may be required, as well as a flow computer and a combustion gas analyzer. A set of hand tools and standard test instruments are also required, which include an electrical multimeter, temperature measurement devices, pressure gauges, tachometers (contact and/or optical), a calculator, and manometers.

9.8 Hazards

On-site activities present a potential for personal injury to personnel. Prudent safety precautions shall be taken at all times. Obtain and use (wear) whatever safety equipment is required, such as seat belts, safety glasses, hard hats, and hearing protectors.

9.9 Calibration and Standardization

The test equipment and sensors used in a BSEE have specific maintenance and calibration requirements as specified by the manufacturer. All equipment shall be maintained in good working condition and calibrated periodically.

Maintenance and calibration records for the test equipment shall be maintained as part of the MEL project files.

9.10 Procedure

This procedure describes the processes required to perform boiler system efficiency testing. Necessary precursors to the actual efficiency testing of initial plant overview, instrumentation evaluation, and tune-up recommendations, as well as data collection forms and reporting formats are included.

9.10.1 Performing Initial Boiler Plant Overview

When a boiler has been identified as a candidate for efficiency evaluation, an informal site evaluation shall be performed. Make arrangements for a walk through of the boiler plant with a knowledgeable site representative to confirm gross characteristics and conditions at the site. The MEL field engineer should be very observant of what exists at the plant and the attitudes of plant personnel. Offhand remarks can sometimes reveal the real cause of problems better than expensive evaluations.

Prepare a general layout sketch of the boiler plant, noting locations of key components such as control panels, pumping stations, and access points.

Collect nameplate characteristic information from the boiler and other major components, such as burners and controllers, and record this information on the Data Collection form contained in Appendix A.

Record the general condition of the boiler, paying particular attention to the level of maintenance. If gauges are clean and in working order, and if major valves and piping runs are clearly labeled, subsequent testing will be easier and quicker. Also record any indications of recent recalibrations.

Determine the size/load relationship; i.e., is the boiler consistently operated at maximum rating or is it operated in the bottom percentages of its capability. This relationship can be obtained by examining steam flow recorders and from conversations with plant operators.

The initial boiler plant overview should also include a combustion efficiency test. Complete instructions for this test are included with the combustion gas analyzer. Perform this test at the current boiler firing rate. This test is intended to be a gross representation of the tune-up condition of the boiler, not an absolute efficiency rating. Record test results on the Combustion Efficiency Test form provided in Appendix B.

Document this initial overview in a brief written report that includes copies of the Data Collection and Combustion Efficiency Test forms, general observations, and specific recommendations.

9.10.2 Evaluating Instrumentation

Modern boiler plants are complex systems that require sophisticated instrumentation to understand their operating condition and to assist in maintaining reasonable levels of efficiency. Accurate and reliable boiler instruments are essential in any program aimed at improving energy efficiency and critical for continued safe operation.

Use the information obtained in the initial boiler plant overview to thoroughly evaluate the existing instrumentation at the boiler, and develop a list of recommendations to correct deficiencies and enhance capabilities based on current technologies.

Begin with existing instrumentation and identify each device's working condition, calibration date, repairability, or recommendation for replacement. Boilers that appear to be sound with several operating years remaining, but have antiquated and inoperable instrumentation, shall be evaluated for complete new instrumentation systems.

The Instrumentation Evaluation form (see Appendix C) is provided to collect information on the condition of existing boiler plant instrumentation. Prepare a report at the conclusion of the instrumentation evaluation with a complete set of recommendations to repair/upgrade the instrumentation to a reasonable operating condition.

9.10.3 Preparing Boiler Tune-Up Recommendations

Based on the initial boiler plant overview and evaluations of the boiler plant instrumentation, prepare a set of recommendations for boiler tune-up. Sometimes the instrumentation will be in such poor condition that development of these recommendations must wait until a reasonable set of functional boiler instruments are installed. A special instrument deficiency report shall be prepared if the instrumentation is inadequate.

Each boiler has a set of operational guidelines for key parameters, such as excess air, carbon monoxide, and carbon dioxide content of flue gases, induced draft (ID) and forced draft (FD) airstream pressures, and acceptable heat exchanger temperatures. If these operational guidelines cannot be located, the MEL field team shall help develop these guidelines based on professional experience and consultation with boiler and burner representatives. The site boiler operators shall bring the boiler within the acceptable parameters of operation.

Examine heat exchanger surfaces for reasonable cleanliness. Boiler water shall be chemically balanced and of acceptable quality. Mechanisms for cleaning and/or blowing down shall be in good working condition. Burners and fuel handling systems shall also function properly.

Identify other energy efficient issues, such as steam leaks and bad steam traps, within the boiler plant.

Prepare a report that identifies specific tune-up deficiencies. Correction of these problems shall be the responsibility of site representatives.

9.10.4 Testing Boiler Plant Efficiency

When a complete boiler plant efficiency test is required, follow the procedures for steam generating units in the ASME Power Test Code (ASME 1974). This procedure provides complete instructions for testing steam generating units to determine efficiency, capacity, and other related operating characteristics. Worksheets and reporting forms, as well as complete procedures, are included.

Two basic procedures for efficiency testing are presented in the ASME test code (ASME 1974), which are the direct measurement of boiler input and output (the input-output method), and the

direct measurement of heat loss plus the direct measurement of input or output (the heat-loss method). The input-output method requires accurate measurement of the quantity and high-heat value of the fuel, heat credits, and the heat absorbed by the working fluid or fluids. The heat-loss method requires the determination of losses and heat credits, plus the total heat input or heat output. Usually a simplified or abbreviated efficiency test that considers only the major losses and the chemical heat of the fuel is an acceptable alternative.

9.11 Calculation or Interpretation of Results

Detailed computational procedures for determining boiler gross efficiency by either the input-output method or the heat-loss method are presented in the ASME test codes, Section 7 (ASME 1974).

9.12 Report

Prepare a complete and concise report for each part of the boiler system that is evaluated. This report shall identify the problem(s), evaluation tests performed, and results of specific measurements.

9.13 Precision and Bias

Tolerances and limits of errors associated with boiler system efficiency testing are presented in ASME test codes, Section 3.03 (ASME 1974), as well as a table showing the approximate effect of measurement errors on the calculated boiler system efficiency.

9.14 Annexes and Appendixes

9.14.1 Annexes

ASME	American Society of Mechanical Engineers
BSEE	boiler system efficiency evaluations
FD	forced draft
ID	induced draft
MAP	MEL Application Plan
MEL	Mobile Energy Laboratory

9.14.2 Appendixes

The Data Collection form, which is used to record nameplate characteristics from boilers and other major components, is contained in Appendix A.

The Combustion Efficiency Test form, which is used to record the results of combustion efficiency tests, is contained in Appendix B.

Appendix C contains the Instrumentation Evaluation form, which is used to collect information on the condition of existing boiler plant instrumentation.

9.15 Personnel Support

Boiler system efficiency testing requires that an extensive set of measurements and calibrations be applied to a range of different mechanical devices. Individuals conducting these tests must be familiar with this process, as well as with boiler and steam plant equipment. Small boilers may be tested by a single individual, but larger plants and complete efficiency testing requires two or three individuals to ensure that the boiler operates in accordance with the test requirements, and that the correct data is collected and plotted.

Individuals conducting these tests should have formal engineering qualifications, as well as direct experience in conducting boiler tests. If a team of individuals is involved, the team leader shall have management responsibility to ensure efficient operation.

One individual involved with testing shall be familiar with the specific boiler/steam plant being evaluated. This individual shall be temporarily assigned to the testing team from the facility being evaluated.

Any additional individuals involved shall be familiar with the general process and possess the required skills for careful and precise reading and recording of test data.

9.16 Testing Schedule

The size, complexity, age, and condition of the boiler system being evaluated affect the boiler system efficiency testing schedule. A typical medium-size boiler, in good condition, should require one-half day for the initial boiler plant overview, one-half day for the instrumentation evaluation, and one-half day for the tune-up recommendations. The efficiency testing should take one to two days to complete, depending on successful maintenance of the boiler operation during the test. Replacement/overhaul of components, cleaning, and actual tune-up activities are not included in any of these time estimates. Actual site conditions may inflate any of these estimates by several days.

Appendix A

Boiler Plant Overview Data Collection

Completed by: _____ Date: _____
Location: _____
Building Identification: _____
Boiler Identification: _____
Site Contact: _____

BOILER SYSTEM DATA

Manufacturer: _____ Model Number: _____
Capacity: _____ Working Pressure: _____
Type: _____ Date of Manufacture: _____
Primary Fuel: _____ Secondary Fuel: _____
Burner Manufacturer: _____ Burner Type: _____
Primary Fuel: _____ Annual Consumption: _____

Secondary Fuel: _____ Annual Consumption: _____
Economizer: _____ Air Heater: _____
Heat Exchangers: _____ Blowdown Valving: _____

GENERAL SITE CONDITIONS FROM VISUAL INSPECTION

Boiler: _____

Controls: _____

Instrumentation: _____

Appendix B

Boiler Plant Overview Combustion Efficiency Test

Completed by: _____ Date: _____

Location: _____

Building Identification: _____

Boiler Identification: _____

Fuel Type: _____

Percent Load: _____

Fuel Rate: _____

Steam Flow: _____

Steam Pressure: _____

Flue Gas

CO₂ _____

CO _____

O₂ _____

Temperature _____

Draft

Windbox _____

Furnace _____

Uptakes _____

Ambient Temperature _____

Fuel

COMBUSTION EFFICIENCY _____

PERCENT EXCESS AIR _____

Appendix C

Boiler Plant Overview - Instrumentation Evaluation

Completed by: _____ Date: _____

Location: _____

Building Identification: _____

Boiler Identification: _____

Instrumentation Calibration

Existence

Functioning

portable flue gas analyzer kit .	_____	_____
flue gas analysis piping	_____	_____
steam flow recorder	_____	_____
air flow recorder	_____	_____
oxygen analyzer	_____	_____
oxygen recorder	_____	_____
combustion analyzer	_____	_____
combustion recorder	_____	_____
smoke indicator	_____	_____
smoke recorder	_____	_____
fuel flow meter	_____	_____
fuel flow recorder	_____	_____
flue gas temperature indicator .	_____	_____
flue gas temperature recorder . .	_____	_____
feedwater temperature indicator .	_____	_____
feedwater temperature recorder .	_____	_____
flame scanner	_____	_____
windbox pressure draft gauge . .	_____	_____
furnace pressure draft gauge . .	_____	_____
fuel temperature indicator . . .	_____	_____
feedwater flow indicator	_____	_____
feedwater flow recorder	_____	_____

Comments: _____

Mobile Energy Laboratory
Procedure 10.0

Infrared Thermography

10.0 Infrared Thermography

10.1 Introduction

Detection of excessive energy usage is a primary objective of energy measurement and assessment in any facility. Monitoring electrical energy transport into a facility provides a gross assessment of the energy usage baseline and a means of monitoring improvement under varying use conditions. However, without a network of distributed point sensors to monitor usage at multiple nodes throughout the facility, it is difficult to associate potentially excessive energy use with a node representing a physical location or piece of equipment.

Infrared (IR) thermography has demonstrated a capability for providing imagery in energy audits that can be readily interpreted as a temperature map at the first order qualitative level where white is hot and black is cold at the extremes of a gray scale. When interpreted relative to the associated physical scenario, high- and low-temperature anomalies can be associated with high or low resistance to energy flow according to the mechanism, such as electrical current, heat flow, steam flow.

IR thermography has a history of application in government and industry in evaluating roofs from airborne platforms; mapping infiltration and exfiltration in buildings, from both interior and exterior imagery; locating thermal bridges; identifying areas of missing, wet or improperly installed insulation; identifying malfunctioning electrical transformers, motors, and transmission lines from excessive Joule heating; identifying malfunctioning mechanical equipment by imaging heat from excessive friction; identifying malfunctioning steam traps, heat exchanger lines and transfer lines; as well as a variety of other applications.

This procedure defines a systematic approach to acquiring consistent thermal imagery that can be interpreted qualitatively to locate thermal anomalies in structures and equipment.

10.2 Scope

This procedure describes a testing methodology for using IR thermography instrumentation in the identification and evaluation of apparent temperature anomalies potentially associated with anomalous heat transfer. This method is applicable to building envelopes; electrical devices and transmission systems; steam, hot, or chilled water distribution systems; and mechanical machinery.

IR thermography is qualitative, relying on a photointerpretation of patterns in two dimensional imagery. Experience in interpreting thermograms, which results in an awareness of potential misinterpretations, i.e., varying emissivity and effects of shading and secondary heat sources, establishes the degree that subtle effects can be accurately interpreted.

Only under carefully controlled and monitored conditions, carefully calibrated image acquisition, and incorporation of extensive supplementary data, can thermograms be used quantitatively for the determination of R-values or other measures of thermal resistance. This procedure does not prescribe the data acquisition, calibration, or analysis steps needed to produce acceptable quantitative results.

Comparisons should not be considered reliable if imaged structures are widely separated in time or space. For example, in aerial roof surveys, comparisons should not be made between roofs, but rather between different areas of the same roof. If supplementary measurements are used to determine that the ambient conditions and emittances are comparable to a high degree of confidence, qualified comparisons may be made.

10.3 Referenced Documents

American Society for Testing Materials (ASTM). 1990. *Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*. ASTM C 1060-90 Standard, Philadelphia, Pennsylvania.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. (ASHRAE). 1981. *Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics*. ANSI/ASHRAE Standard 101-1981, Atlanta, Georgia.

Inframetrics, Inc. 1989. *Inframetrics Model 600L IR Imaging Radiometer Operator's Manual*. Waltham, Massachusetts.

Infraspection Institute. 1988. *Guidelines for Specifying and Performing Infrared Inspections*. Shelburne, Vermont.

10.4 Terminology

A detailed glossary of terms is contained in Appendix A.

The values stated in acceptable metric units are to be regarded as standard.

10.5 Summary of Procedure

IR thermography is a nonintrusive survey method; therefore, facilities or equipment being surveyed shall not be disrupted unless survey surfaces must be surveyed that are physically blocked from direct view and require that equipment or structures be moved. Because surveys require a minimum ΔT to provide a sufficient thermal gradient, it may be necessary to temporarily modify the building environment.

The flowchart shown in Figure 10.1 provides a representation of the key activities required to complete an IR thermography survey.

This procedure provides a common basis for several IR survey applications. More specific guidelines for building surveys are discussed in Appendix B, and the specific application for aerial roof surveys is addressed in Appendix C. Aerial roof surveys are treated in some detail in the

Figure 10.1. Flowchart of Image Infrared Thermography Activities

discontinued ANSI/ASHRAE (1981) 101-1981 Standard. In addition, this test method is readily adapted to inspection of potentially faulty electrical or mechanical equipment, or potentially faulty gaseous or fluid transfer lines. Neither ASTM (1990) Standard C 1060-90 or ANSI/ASHRAE (1981) 101-1981 address IR procedures for nonbuilding envelope surveys, but the same general set of procedures applies.

IR thermography provides two dimensional imagery of the IR radiance distribution from structures or other objects of interest. Within defined ambient conditions, and for surfaces having

comparable IR emission properties, the resulting video gray scale is a measure of the temperature of the surface. Temperature anomalies can be qualitatively interpreted as locations of higher or lower thermal flux than surrounding areas. Under more rigidly controlled conditions, and with appropriately calibrated instrumentation, gray scales can be more quantitatively interpreted to provide temperature indices and R-values.

In practice, an IR radiometer is comounted with a black and white video camera. The structure being surveyed is scanned by both, each providing a video image of the structure in its spectral band. Recording the visual image provides a reference so that the IR image can be more readily correlated with real-world objects when replayed in the laboratory. Radiometer capability provides for real-time pseudocolor image enhancement and isothermal display for real-time identification of anomalies. It also provides the capability to directly read point or area averaged apparent temperatures. Anomalies can be identified in real time from the system display or recorded for later analysis.

10.6 Significance and Use

IR thermography provides a fast way to survey large areas for temperature anomalies that can represent missing, wet, or improperly installed insulation; thermal bridges; air leakage paths; and faulty electrical or mechanical equipment. It is primarily a qualitative method relying on the photointerpretation of a gray scale or pseudocolored patterns in displayed images. However, when used in conjunction with other elements of an energy audit, IR thermography is a powerful tool for understanding the energy flow through a building.

The only domestic standard currently in effect for IR inspections is ASTM C 1060-90, which deals with the inspection of insulation in cavities of frame buildings. This procedure combines features of ASTM (1990) C 1060-90, ANSI/ASHRAE (1981) 101-1981, Infrasppection Institute (1988), other published sources, and the instrument manufacturer's user's guide to provide a procedure for IR thermography of various structures using a specific instrument.

10.7 Interferences

Interferences consist of any source of nonuniformity in the image that may be misinterpreted as a thermal anomaly. The most typical of these include nonuniform surface emittance and environmental factors such as ambient sources of IR energy, nonuniform sky conditions, and wind and shading. Gray scale variations can only be interpreted directly and accurately as temperature variations with uniform, hemispherical IR flux falling on a surface of interest with known, uniform emittance.

10.8 Apparatus

The specific apparatus^(a) for this procedure consists of an Inframetrics Model 600 IR Imaging Radiometer operating in the 8 μm to 14 μm spectral band, which uses liquid nitrogen (LN_2) as the

(a) References to specific manufacturers and models are not to be construed as an endorsement as compared to equivalent instrumentation available from other manufacturers.

cooling agent. A black and white video camera equipped with a zoom lens is comounted to provide visible light imagery. Two video monitors provide real-time monitoring, and two video cassette recorders (VCRs) provide hard copy for the IR and visible light images. The video record can be used as input to an image processing system for subsequent processing and/or to provide hard copy using a color video copy processor. The video copy processor referred to in this procedure is a Mitsubishi Model CP200U, which is capable of producing black and white, color, or color transparency copies by using the appropriate materials.

The referenced postprocessing system consists of an IBM PC-XT computer with a video frame digitizing expansion board, which is compatible with ThermoGram 1.07 image analysis software. The system is distributed by Inframetrics as an option to their imaging radiometer line.

The minimum apparatus acts as

- an IR sensor system operating within the 2— μm to 14 μm spectral region, which is capable of either line scan operation or providing a two dimensional image of the IR radiance of the surface of interest
- a way to collect supplemental data (temperatures, wind speed and direction, visible light images)
- a way to generate a hard copy of the images.

If a VCR is used to obtain a hard copy, an audio microphone is useful by allowing for verbal annotation while collecting data.

Additional supporting apparatus may be necessary, depending on the primary apparatus choice. For example, if an IR detector operating in the 8 μm to 14 μm spectral range is used, either an appropriate closed-cycle cooler (typically an integral part of the sensor) or cryogenic liquid-handling capability are required. Hard copy can be video tapes, photographs, or computer based. In each case, appropriate supplemental apparatus and supplies are required.

If postprocessing of imagery is needed, a computer, video frame digitizer, and compatible image processing software are needed.

10.9 Reagents and Materials

The system used for postprocessing of imagery requires LN₂ to cool the radiometer, video tape and floppy disks for data storage, and expendables for the video printer.

10.10 Hazards

All field activities present a potential for personal injury to personnel. The IR thermography testing method subjects personnel to hazards associated with handling cryogenic liquids. This hazard can be eliminated by selecting a radiometer that uses other noncryogenic, liquid-cooling technologies.

Other hazards associated with IR thermography may include proximity to electrical power transmission components and systems, thermal sources, or operation from an airborne platform.

When handling LN₂, gloves and protective eyewear shall be used when transferring the liquid between containers or charging the dewar of the radiometer. Specific procedures for handling LN₂ are described in the Pacific Northwest Laboratory (PNL) manual containing procedures for handling LN₂.

This test method does not address all of the safety issues associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to its use.

10.11 Preparation of Apparatus

Mount and interconnect the system components (radiometer head and control unit, video camera, monitors, and VCRs) on the system cart. Keep monitors at least 150 mm (6 in.) from the scanner (radiometer head) to avoid interference.

Slowly fill the radiometer dewar with LN₂, pausing periodically for 10 to 15 seconds to allow the temperature to stabilize. The LN₂ will boil violently, especially as the dewar approaches equilibrium temperature, ejecting LN₂ from the mouth of the dewar; therefore, avoid positioning face over the dewar opening. The dewar is full when the level is approximately 12.5 mm (1/2 in.) below the top of the dewar. This is the location where the narrow neck of the dewar enlarges to its inside diameter.

Turn the power on to all components and allow approximately 30 seconds for the system to stabilize. The initial display is a Gray Scale Test Pattern. In addition to the gray scale, the current date and time, the power-up default maximum and minimum temperatures, and the power-up default emittance are displayed. If necessary, reset the date and time. If any warning messages are displayed on the radiometer monitor, correct the condition or note the warning message and the fact that measurements may not be valid in the field notebook, or in the space labeled "Exceptions to Calibration" on the survey forms contained in Appendix D.

Adjust image brightness and contrast on the radiometer monitor so that each of the ten gray scale levels displayed at the bottom of the screen is distinguishable.

Display a real-time image by pressing the IMAGE mode key on the front of the radiometer console.

Focus the radiometer by alternately pressing the NEAR and FAR focus keys on the front of the radiometer console while observing image sharpness.

Adjust the iris of the video camera to provide an image of acceptable brightness. Adjust the video monitor's brightness and contrast. Adjust the zoom control on the video camera to give an image scale approximately the same as that of the IR radiometer image. Focus the video camera for a sharp image.

If necessary, follow the manufacturer's instructions when using the SETUP menu to redefine default values; i.e., background temperature, filter usage, polarity [white=hot or black=hot], center temperature setting method, target emittance, blanking, date/time set. The operator should read the operator's manual (Inframetrics 1989) before making adjustments to ensure understanding of each function and the effect of resetting it before use to optimize performance.

Begin the survey with the power-up default settings. Aim the instrument at the structure to be surveyed. Adjust the CENTER TEMPERATURE using the front panel knob on the radiometer control console so that the nominal ambient temperature is about midway between the displayed upper and lower temperatures. This center temperature can be changed during the survey as required. The temperature range is constantly indicated on the monitor and documented on tape as part of the recorded image.

Set the TEMPERATURE SPAN at the minimum span that includes all temperatures in the scene. In the default black & white mode, this means that all areas of the scene are shades of gray with no areas of black or white. The temperature span can be changed during the survey as required.

Ensure that the radiometer is an appropriate distance from the structure being surveyed to provide adequate resolution for detecting anomalies of an expected size. Because the number of resolvable picture elements (pixels) in an image is fixed, there is a trade-off between field of view (FOV) and resolution. A wide FOV is preferred to maximize the area that can be recorded in a single image, but if fine detail is to be resolved, the magnification must be higher, reducing the FOV. The Inframetrics Model 600 electro-optical zoom does not improve resolution. If higher resolution is needed, the radiometer must be moved closer to the structure or appropriate optional optical magnifiers must be added to the system.

The Inframetrics Model 600 system angular resolution is 2.4 mR so that at a distance of 5 m (~ 16 ft), pixel footprints in the structure are 12 mm (~ 1/2 in.). Two pixels are generally considered adequate for detection of an anomaly. For reference, Class A (highest level of survey) insulation surveys require (ASHRAE 1981) that a 100 mm (4 in.) square R5 anomaly in an R15 background be detectable. To meet this standard with the Inframetrics Model 600, stand-off distance should be less than 21 m (68 ft) where two pixels have a 100 mm footprint. Greater distances may result in failure to detect anomalies of this size. It would be prudent to locate the instrument conservatively closer to the structure. For smaller anomalies, which may be encountered when surveying for electrical malfunctions, smaller stand-off distance is indicated. For aerial surveys of roofs, greater stand-off dictates lower resolution. From an altitude of 300 m (~ 1000 ft), the detectable anomaly size would be about 1.4 m (4.7 ft). In general, pixel footprint is proportional to the stand-off distance.

Verify proper operation of the recording instruments. Add any desired audio headers to the hard copy to ensure that the record is obviously labeled with time, date, location, operator's name, and other important data.

10.12 Calibration and Standardization

The manufacturer recommends that the radiometer be returned to the factory for periodic

calibration. A warning message is automatically displayed on the screen when the time of the last calibration exceeds one year. Because ASTM (1990) Standard C 1060-90 specifies that the instrumentation shall be operated according to manufacturer's specifications, annual recalibration by the manufacturer is mandatory.

Relative calibration checks can be performed periodically by measuring the temperature of a known source, such as a precision blackbody. Although such a source is also subject to loss of calibration, it may provide an indication of long-term stability. If no change is detected between a baseline measurement and subsequent periodic checks, then the source and radiometer are probably in calibration. If the radiometer is dedicated to surveys, operated by qualified personnel, and used frequently (several times each week), then weekly to monthly relative checks should be adequate. If not, relative checks should be performed on the radiometer prior to each survey.

10.13 Conditioning

Ambient conditions may adversely affect the ease of interpretation of imagery. Appendix E contains guidelines for evaluating whether or not conditions are acceptable. Considerations include ΔT , use of ambient air temperature measurements, solar radiation, and wind.

10.14 Procedure

An initial site survey provides an introduction to the site and facility representatives for the thermography team, as well as for teams who will implement other test methods. Some elements of this initial site survey are common to all teams, other elements are unique to thermography.

10.14.1 Collecting Background Information

Background information on the site shall be assembled as a planning aid and for later interpretation. Information that is not specifically recorded on a survey form shall be recorded in a field notebook. For building envelope surveys, record the following background data:

- any anticipated thermal patterns by visually inspecting structures to be surveyed and/or studying construction drawings - Organize notes in the order that elements of the structure are expected to be surveyed.
- additions or modifications to the structure that are not documented in the construction drawings
- any *a priori* information provided by the facility representative responsible for the structure, which are related to problems or unusual events that might result in, or be related to, thermal anomalies or interferences
- any differences in surface materials or conditions that may affect emittance, which include metallic finishes, polished surfaces, stains, or moisture - These conditions result in thermal pattern differences independent of temperature differences.

- the geographical orientation of the structure - For interior structures, note relative location of windows, potential sources of heat, and potential structures that may shade the structure from sources of heat. For exterior structures, note potential sources of heat, potential shading structures, and internal sources of heat adjacent to exterior walls.

10.14.2 Performing Thermographic Inspection

A quick preliminary thermographic inspection may be appropriate to identify suspect areas needing more detailed examination. This inspection may be done from an airborne platform, moderate exterior stand-off distance, or by rapid scanning of interior walls. Quick surveys of operating equipment and building envelopes can also be performed by using these methods.

10.14.3 Assembling and Preparing Radiometer

After arriving on site, assemble and prepare the radiometer according to the operator's manual.

Note any new information regarding the facility to supplement interpretation of IR and visual imagery. Record the wind speed and direction, exterior ambient temperature, interior temperature, and precipitation conditions, and note significant changes during the inspection.

The minimum resolvable temperature difference (MRTD) is selected by the operator down to the instrument limit. For building envelope surveys, the required difference is a function of wind speed and inside/outside temperature difference. Appendix F contains plots that define the required MRTD as a function of wind speed and inside/outside temperature difference for aerial roof surveys and exterior building envelope surveys. The smallest MRTD under the conditions shown is $\sim 0.1^{\circ}\text{C}$. This is the typical Inframetrics Model 600 performance. However, to display and measure temperature difference with this sensitivity, the radiometer must be set to a small TEMPERATURE SPAN. Thus, it may be preferable to set the TEMPERATURE SPAN at a small value and allow hot and cold features to saturate or be below the threshold, respectively, to maintain the required MRTD. If hotter or cooler features are observed, the CENTER TEMPERATURE can easily be shifted to focus on the feature.

If the survey will be recorded rather than interpreted in real-time, record in the black and white mode (as compared to pseudocolor). If required, pseudocolor may be introduced in postprocessing for contrast enhancement or presentation graphics, and all imagery may be digitized for various image enhancements and measurements. However, if the original hard copy is pseudocolored, special hardware is required for processing. If greater contrast discrimination is desired in real time, select the COLOR mode using the appropriate function key to pseudocolor the real-time display.

If there will be no real-time measurements, operate the radiometer in the IMAGE mode, as compared to the POINT, AREA, or ISO (therm) modes. Raw data is acquired in the IMAGE mode. Point or area measurements may be made, and isotherm contours added, using the hard copy and associated image processing. If real-time measurements will be made, they should be hard copied to the video tape as they are made. In the POINT and AREA modes, the SOFT KEYS move the cursor. In the ISO mode, the CENTER TEMPERATURE knob sets the isotherm level.

If a less than full FOV anomaly is of interest, the electro-optical zoom should be employed to obtain a view of the anomaly that fills the FOV. The FOV is 60° x 80° when unzoomed and 15° x 20° when fully zoomed. Although this does not improve spatial resolution, it does allow for a more precise positioning of the cursor in postprocessing. For building envelopes, the FOV should be at least two framing spaces wide by one framing space high for interior surveys, and one floor-to-ceiling height wide by one and one-half times that amount wide for exterior surveys.

If quantitative temperature measurements are desired, redefine the emissivity of the surface to be surveyed. The default emissivity is 1.00 indicating a perfect blackbody. The instrument operator's manual tabulates the emissivity of a variety of common materials at various temperatures. The table is not comprehensive because practical considerations limit it to relatively few materials, temperatures, and subjectively described (completely rusted) surface conditions. For noncritical measurements, surface emittances can be used as an approximation. For critical measurements, the operator's manual describes two methods for measuring the emittance of a known surface temperature using the Inframetrics Model 600, which should be used to obtain an accurate emittance. When default emittance is then redefined as this value, the temperature can be read directly (other interferences being negligible).

10.14.4 Performing Infrared Thermography Test

Perform the IR thermography test by recording IR and visual images of the facility. As needed, move the system to cover the entire surface to be surveyed. Take primary data along a line of sight (LOS) as close to normal incidence as practical. In addition, scan at oblique LOS angles on both sides of normal incidence. These data help to discriminate reflections from real anomalies when the imagery is interpreted.

Annotate the imagery in writing, referenced to the VCR counter, or verbally on the tape to highlight features of interest and supporting information. Record any structural features in the vicinity that may help interpret the imagery later. If a microphone is used, narrate the survey as a record.

10.15 Calculation or Interpretation of Results

The scope of this procedure encompasses only qualitative photointerpretation of the resultant imagery. In the default **WHITE = HOT** mode where high-temperature anomalies are brighter compared to surrounding areas and low-temperature anomalies are darker compared to surrounding areas, potential temperature anomalies are readily detected by simple visual inspection.

If the temperature range and expected temperature difference is small, it may be advantageous to postprocess the imagery using specialized computer hardware and software designed to interpret the gray scale of the monochrome video as a temperature scale. Most of the features available in real-time operation are available in postprocessing. One feature that is simple to implement is pseudocoloring, which enhances perceived contrast. Others are also available, such as video frame averaging, which reduces image noise.

The software is menu driven, user friendly, and relatively intuitive. For example, pseudocoloring may be initiated by a single keystroke.

In addition to visual enhancement, the software provides a way to make point or area average temperature measurements, make spatial measurements, display histograms of temperature distribution, generate line profiles, as well as a wide variety of other image and data manipulations.

Interpretation of thermograms is enhanced by a knowledge of the technology involved in the facility. The background information previously collected may be used to supplement the thermography.

10.16 Report

Prepare a complete and concise report for each IR thermography procedure that is performed. This report shall include qualitative imagery consisting of hard-copy images that are annotated and interpreted in the text of the report. A systematic record of conditions should accompany these images, which may include the following:

- the sample survey data forms, which are intended to include relevant data that may be useful in interpreting imagery - These surveys, however, are not comprehensive and additional observations that may be potentially useful should be added in a field notebook.
- a monochrome video image for each individual IR FOV that is important enough to be included in the report - If multiple images of a single FOV are used, a single monochrome video image is enough for reference. Monochrome video images can be printed using a video copy processor. The images should be identified in a caption that should include date, time, location, and VCR index for the image. Because processing can be misleading, the caption or narrative should clearly describe the applied postprocessing and the displayed temperature range.

10.17 Precision and Bias

The Inframetrics Model 600 is capable of an MRTD of 0.1°C . The noise equivalent temperature difference is 0.2°C . The read-out, however, is a function of the selected temperature range. The digital temperature read-out displayed on the screen is three digits. The palette may be defined by the user so that the image can be displayed in various numbers of temperature increments. The default black and white palette consists of a continuous gray scale. Pseudocolor palettes may be selected with up to 20 colors. Because the temperature spans (in the normal temperature range, compared to the extended range) are 5°C , 10°C , 20°C , 50°C , 100°C , and 200°C , the default black and white palette displays an image with a digital read-out precision of 0.01°C to 1°C , respectively. Pseudocolor display image palettes have a precision of 0.25°C to 10°C , respectively, but a digital read-out with the same precision as the black and white palette.

There should be no systematic bias if the system is in calibration. Interferences, like reflected IR energy, may introduce a bias, but it is dependent on geometry, not instrument bias.

10.18 Annexes and Appendixes

10.18.1 Annexes

ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc.
ASTM	American Society for Testing Materials
FOV	field of view
HVAC	heating, ventilating, and air conditioning
IFOV	instantaneous field of view
IR	Infrared
LN₂	liquid nitrogen
LOS	line of sight
MRTD	minimum resolvable temperature difference
PNL	Pacific Northwest Laboratory
TI	temperature index
VCR	video cassette recorder

10.18.2 Appendixes

Appendix A contains a detailed glossary of terms.

Guidelines for Interpretation of Building Surveys are contained in Appendix B.

Appendix C contains the specific application for aerial roof surveys.

Survey forms are contained in Appendix D.

Guidelines for evaluating ambient conditions for IR surveys are contained in Appendix E.

Appendix F contains plots that define system performance dependence on wind.

10.19 Personnel Support

The use and application of IR thermography in energy audits is subjective and highly dependent on the expertise and knowledge of the individuals conducting the survey. The thermographic survey team shall include facility representatives and a MEL team of field engineers. The MEL team shall provide highly skilled and knowledgeable individuals with operational and interpretation expertise in IR thermography. The facility representatives shall supplement the team by providing knowledge of the structures being surveyed and, when necessary, access to heating, ventilating, and air-conditioning (HVAC) control. The team shall include:

- **Team Leader** - IR thermographic surveys not only integrate diverse technologies, but also diverse work cultures because of the interests and priorities of its practitioners. Thus, effective team leadership requires a very broad understanding of several disciplines (IR thermography; heat transfer in and around structures by conduction, convection, and radiation; building construction;

field data acquisition; meteorology; and image processing), and an ability to integrate diverse capabilities and cultures. The team leader must have sufficient working knowledge of these disciplines to direct team members and skill in interpersonal relationships.

- **IR Radiometer Operator** - The IR Radiometer operator shall be an individual with considerable experience using all modes of the radiometer and setting variations, and a good understanding of the impact of various parameters on operation. This individual should have a working knowledge of building construction and energy surveys and their relationship to IR thermographic interpretation. This experience supplements the team leader's experience by providing a greater depth of knowledge in radiometer capabilities, as well as some knowledge of practical survey requirements and the interpretation process. Because there are so many variables that can affect IR imagery, operator experience is required to gain reliable, easily interpreted primary imagery. The operator should attend a training course on the use of radiometers that is instrument specific; e.g., a course offered by Inframetrics, Inc.
- **Interpreter** - If the team leader or the operator are not also the interpreter, a trained interpreter shall be required. Because survey results are subjectively photointerpreted, an experienced interpreter is critical for producing reliable survey results. The interpreter must have extensive knowledge of building construction and IR thermography. Experience using relevant image processing software is also useful. Image processing system experience can be enhanced with a nominal amount of training, which improves significantly with continued use. The interpreter should attend an Inframetrics, Inc. training course.
- **Pilot** - If an aerial roof survey is to be conducted, a qualified pilot is required.
- **Technician** - A technician is required to monitor various instrumentation under the direction of the team leader or operator. This individual must be capable of operating other instrumentation for acquisition of temperature, wind speed and direction, and other data. A technician experienced in video camera operation is useful because this will allow the radiometer operator to optimize IR imagery.
- **Plant Supervisor** - A building, or plant, supervisor(s) who is knowledgeable in the building's construction, has access to construction drawings and utility drawings, and is authorized to temporarily (up to 24 hours) modify HVAC parameters is required. This individual should be able to indicate potential areas of concern, provide information on problems, and provide background on building characteristics.
- **Laborers** - If any equipment or structures must be moved, the facility shall provide appropriate labor and supervision, consistent with the facility's operations policies.

10.20 Testing Schedule

The testing schedule for IR thermography depends on the size and scope of the survey and on compliance with ambient condition requirements. The following testing schedule identifies the various tasks that a survey program may be divided into. Time estimates, where included, are for a

single, one or two story, industrial building having no unusual complications.

10.20.1 Initial Site Survey

After a site has been identified for IR thermography, an initial site survey shall be performed. At that time, the team leader and selected team members shall visit the site, discuss the scope of the survey, be provided with background information and drawings, and walk through the facility, noting potential positive and negative attributes. A one day visit is adequate preparation for an external survey. The walk through and discussions will each require about one-half day. If a preliminary IR survey is required, at least one additional day is required. Several days to a week may be required for the walk through and discussions supporting an interior survey where a large number of individual rooms are to be surveyed. One to two days are required for evaluation and preparation of a report, recommendations, cost estimate, and schedule.

10.20.2 Building Characteristic Evaluation and Survey Planning

A detailed evaluation of the building characteristic data and detailed survey planning requires two to three days, plus an additional day to formalize the plan as a document.

10.20.3 Survey and Data Collection

Two to three days are required for an exterior survey. Five to ten days may be required for an interior survey, depending on the number of surfaces to be surveyed and complications.

10.20.4 Interpretation

Interpretation is highly variable, depending on the number of potential anomalies to be analyzed and the difficulty in identifying a cause. Ancillary data shall be compiled in a manner that enables the interpreter to correlate it with IR images. This compilation may require one day, depending on the amount and type of data. An actual study and interpretation of thermograms also have varying schedules, depending on the complexity of the structure and range of potential sources of anomalies. As an approximation, several "average" thermograms may be processed and interpreted in one hour if supporting ancillary images and data are organized for efficient access. This schedule assumes relatively simple image processing, several actual measurements or line scans per image, and printing a hard copy of the thermogram.

10.20.5 Report Preparation

Preparation of a report depends on the size, scope, and complexity of the survey. It may take one day to survey a single piece of equipment, a few days for a single building exterior survey, and one month or more for a multiple surface interior survey or a survey of multiple pieces of equipment. Reports shall include a significant amount of full color graphic illustrations and may be accompanied by edited video tape.

10.20.6 Maintenance

The imaging IR radiometer is the primary instrument used in IR thermography, which requires regular maintenance. Assuming regular moderate usage (20 to 40 hours per month), a relative calibration check should be performed monthly or prior to each test series. This takes a maximum of several hours per calibration check. The instrument must be returned to the manufacturer for certified calibration once a year. At that time, a routine operational checkup and service should be performed, which requires PNL to ship the equipment and verify equipment operation when returned. There is a service fee charged by the manufacturer for the calibration.

10.21 Delivery Requirements

The report discussed in Section 10.16 of this procedure shall be delivered to the site contact. The report shall describe the objective of the survey, potential problems of interest, conditions under which the survey was conducted, data, and results. It is appropriate to illustrate the report with thoroughly annotated black and white video and/or hard copy, as well as IR video and/or hard copy. Recommendations regarding additional surveys, independent supporting verification, supplementary measurements or studies, or corrective actions are appropriate.

Delivery schedules depend on the magnitude of the interpretation task. They are negotiable, but should conform to acceptable practices.

Appendix A

Glossary

airborne infrared survey. See survey, airborne infrared.

airborne thermography. See survey, airborne infrared.

anomalies, thermal. The heat loss characteristics of a structure that are not in accordance with intended design characteristics.

anomalous thermal image. An observed thermal pattern of a structure that is not in accordance with the expected thermal pattern.

apparent radiant temperature. See temperature, apparent.

apparent thermal resistance. See resistance, apparent thermal, range of.

background. The irradiance at the entrance aperture of the infrared sensing system which is not radiated directly from the object being investigated.

blackbody. An ideal thermal radiator (emissivity = 1.0), which emits and absorbs the maximum theoretically available amount of thermal radiation at a given temperature.

bridge, thermal. A lower thermal resistance path connecting two surfaces.

building heat loss characteristics. See characteristics, building heat loss.

characteristics, building heat loss. Those properties of a structure that pertain to the loss of energy through the building envelope.

coefficient, convective film. Constant of proportionality relating the convective rate of heat transfer at a surface to the temperature difference across the air film on that surface.

coefficient, radiation. Constant of proportionality that relates the radiation energy exchange between a surface and its surroundings to the temperature difference between the surface and its surroundings.

convective film coefficient. See coefficient, convective film.

copy, hard. See record, hard copy.

detector, infrared. A device that transduces the infrared irradiance incident upon it into some other

form of energy; in most cases electrical.

device, infrared sensing. A wide class of instruments used to display and/or record information that is proportional to or equivalent to the thermal radiation from any object surfaces viewed by the instrument. The instrumentation varies in complexity from simple spot radiometers that measure only one "spot" or area to full two-dimensional thermal imagers that provide photographic type quality pictures, which map the scene radiosity.

difference, minimum resolvable temperature (MRTD). A measure of the ability of an infrared imaging system to allow the human observer to recognize periodic bar targets on the display. The MRTD is the minimum temperature difference between a standard periodic test pattern (7:1 aspect ratio, 4 bar) and its blackbody background where an observer can resolve the pattern as a four-bar pattern. Unlimited viewing time, and optimization of instrument level and gain controls are allowed.

difference, noise equivalent temperature (NET). A measure of the noise of an infrared imaging system or line scanner. It is the target to background temperature difference between a low spatial frequency blackbody target and its blackbody background, where a ratio of one is obtained between the peak-to-peak-signal and RMS noise at the output of the detector processing electronics of the sensor in question.

emittance, surface. The ratio of radiant energy from a surface at a given temperature to the corresponding radiant energy from a blackbody surface at the same temperature.

envelope. The construction, taken as a whole or in part, that separates the indoors of a building from the outdoors.

equilibrium, thermal. Condition where heat flow through a structure has reached steady-state condition. For building diagnostic purposes, this condition is approached when the environmental conditions remain approximately steady over a

period of time.

equipment-use services. Services provided by companies that use infrared sensing devices to perform heat loss surveys of structures.

exfiltration. Air flow outward through a structure.

exitance. The total radiant flux that leaves a surface per unit area. The exitance is the sum of the radiant flux emitted and reflected by the surface plus any radiant flux transmitted through that surface. See also radiosity and ISO Standard 31/6-1980, "Quantities and Units of Electricity and Magnetism."

FOV. See field of view.

field of view (FOV). The total angular dimensions within which objects can be imaged, recorded, and displayed by an imaging device when pointed in a fixed direction.

field of view, instantaneous (IFOV). The angle in milliradians determined by dividing the size of the sensor's detector by the effective focal length of the sensor's objective lens system, and multiplying by 1000. The IFOV is also called the resolution element.

framing spacing. Distance between the centerlines of joists, studs, or rafters.

hard copy. See record, hard copy.

IFOV. See field of view, instantaneous.

imaging line scanner. See scanner, imaging line.

imaging system. See system, infrared imaging.
index, temperature (TI). A coefficient of thermal performance based upon the ratio of the difference in temperature between the inside surface and exterior ambient, to the difference in temperature between the inside ambient and the exterior ambient across a component of the building envelope. The coefficient can be used to estimate the apparent thermal resistance of the component.

infiltration. Air flow inward through a structure.

infrared sensing device. See device, infrared sensing.

infrared imaging system. See system, infrared imaging.

instantaneous field of view (IFOV). See field of view, instantaneous.

irradiance. The radiant power per unit area incident on a surface.

lag, thermal time. The phase difference in hours between the exterior and interior surface

temperatures when the exterior surface is subjected to a sine wave temperature change having a twenty-four hour period.

line scanner. See scanner, line.

masonry veneer. frame construction with a nonload-bearing exterior masonry surface.

minimum resolvable temperature difference (MRTD). See difference, minimum resolvable temperature (MRTD).

MRTD. See difference, minimum resolvable temperature (MRTD).

nadir. The object point that is directly beneath the aircraft flying an airborne imaging survey.

NE Δ T. See difference, noise equivalent temperature (NE Δ T).

noise equivalent temperature difference (NE Δ T). See difference, noise equivalent temperature (NE Δ T).

object plane resolution. See resolution, object plane.

panning. An infrared surveying procedure where an infrared device is moved back and forth across a subject surface, thereby permitting thermal anomalies to be identified.

pixel. The smallest detected element in a picture - derived from the term *picture element*.

pixel footprint. The element in the viewed scene, which results from projecting the pixel (detector element) backwards through the optical system from the detector to the scene.

radiance. The total radiant flux per unit solid angle per unit projected area that emanates from a surface. It includes the self-emitted radiation plus reflections from sources other than the object of interest as intercepted from the direction of measurement. See also radiosity.

radiation coefficient. See coefficient, radiation.

radiometer, spot. An apparatus that measures the average radiosity or apparent average temperature of the surfaces subtended by its field of view. Because the spot radiometer has no scanning mechanism, its IFOV is the same as its FOV.

radiosity. The total radiant flux that leaves a surface per unit area. The radiosity is the sum of the radiant flux emitted and reflected by the surface, plus any radiant flux transmitted through that surface. See also exitance.

ratio, aspect. The ratio of the length to the width of a rectangle.

record, hard copy. Any permanent record. Typically, the record will consist of photographs, magnetic tapes or some data log documentation.

reflection, thermal. That portion of the radiosity from a surface that is contributed by reflection.

resistance, apparent thermal. A measure of the insulating quality of a building envelope component based on steady-state conditions. For the purposes of this document, the apparent thermal resistance can be approximated by using a procedure such as the TI (thermal index) Method.

resistance, apparent thermal, range of. The apparent thermal resistance of a building, which is determined to a range based on an allowance for the uncertainties of measurement using a procedure such as the TI (thermal index) Method.

resolution, element. See **field of view, instantaneous (IFOV).**

resolution, limiting. The highest spatial frequency of an object space target that an imaging sensor is able to resolve. The spatial frequency of the target is determined by taking the inverse of the ratio of two bar widths divided by the distance from sensor to target. This number is generally multiplied by 1,000 and expressed in cycles per milliradian.

resolution, object plane. The size in the object plane that corresponds to the product of the system's instantaneous field of view in radians, and the distance from the system to the object.

resolution, spatial. The planar angle defined by the instrument instantaneous field of view; i.e., the resolution element.

resolution, thermal. A measure of the capability of an infrared sensing device to distinguish the apparent radiance temperature difference between two blackbodies near the same temperature.

scanner, imaging line. An apparatus that scans in a single dimension and is moved perpendicular to the scan direction to produce a two-dimensional thermal map of the scene. See also **survey, airborne infrared and scanner, line.**

scanner, line. An apparatus that scans along a single line of a scene to provide a thermal mapping of a discrete width or slice of the scene. See also **scanner, imaging line.**

sensing device, infrared. See **device, infrared sensing.**

shading. The percentage of total radiation from the surrounding hemisphere that does not irradiate

a structure surface because of an obscuration.

spatial resolution. See **resolution, spatial.**

spot radiometer. See **radiometer, spot.**

surface emittance. See **emittance, surface.**

survey, airborne infrared. The generation of thermograms of building structures as viewed from an overhead platform using an infrared sensing device.

survey, imaging exterior. The generation of thermograms of building outside surfaces.

survey, imaging interior. The generation of thermograms of portions of a building as viewed from the building interior.

survey, nonimaging. The generation of a set of apparent temperature measurements of building surfaces (usually the interior) obtained with a nonimaging thermal sensing device.

system, infrared imaging. An apparatus that converts the two-dimensional spatial variations in infrared radiance from any object surface into a two-dimensional thermal map of the same scene where variations in radiance are displayed in gradations of gray tones.

temperature, apparent. The temperature of an object as determined from the measured radiance. (see definition of radiance)

temperature, blackbody equivalent (apparent temperature). The apparent temperature of an object as determined from the measurement of its radiance, and the assumption that it is an ideal blackbody with emissivity of 1.0.

temperature index (TI). See **index, temperature (TI).**

thermal anomalies. See **anomalies, thermal.**

thermal bridge. See **bridge, thermal.**

thermal pattern. A representation of colors or tones that indicate surface temperature and emittance variation.

thermal resolution. See **resolution, thermal.**

thermal time lag. See **lag, thermal time.**

thermogram. A photograph or two dimensional record of an image that maps the apparent temperature of the scene as sensed by an infrared imaging system.

thermography. The process of generating a thermogram by using an infrared imaging system, usually with some means of temperature calibration.

thermography, airborne. See **survey, airborne**

Infrared.

TI. See Index, temperature (TI).

time lag. See lag, thermal time.

transmittance. The ratio of radiant energy transmitted through a body to that incident upon it.

vold. For purposes of this document, a void is defined as any localized area of the building envelope that has a significantly different thermal resistance from the area surrounding it. The void may be because of partial or complete absence of insulation.

zone. A volume of a building served by a single ventilation system. For buildings with natural ventilation only, the whole building shall be considered a zone with all interior doors open.

Appendix B

Guidelines for Interpretation of Building Surveys

B.1 Proper interpretation of thermograms allows for the determination of the following information:

B.1.1 Locations of regions where insulation is apparently missing or defective, and the total area of the defect.

B.1.2 Locations of regions where insulation is apparently intact, and the total area.

B.1.3 Location and total area of added insulation (assuming B.1.1 and B.1.2 were determined prior to adding insulation).

B.1.3 Estimated total area of surfaces that cannot be inspected.

B.2 Interpretation of thermograms requires an awareness of the following types of patterns:

B.2.1 Intact Insulation - as seen from the warm side of the construction, dark parallel lines represent the framing and lighter areas between framing represents insulation. As seen from the cool side of the construction, contrast will be reversed - framing will be light and insulation will be dark.

Note: Metal framing with no insulation may fit this description because the metal conducts heat better than air or insulation. If insulation is present, there may be a strong reverse in thermal contrast between the framing and insulation. Verification using alternate methods is advisable.

B.2.2 Insulation Missing Completely - as seen from the warm side of the construction, light parallel lines represent framing and darker areas between framing lines represent empty spaces. Convection may be visible in vertical framing as a gradient from darker (cool) at the bottom of the space to lighter (warm) at the top. As seen from the cool side of the construction, contrast is reversed with framing light and insulation dark and convection still lighter at the top.

Note: Metal framing with no insulation may not fit this pattern. See note under B.2.1.

B.2.3 Insulation Partly Missing - The dominant effect is described in B.2.1, but with well defined areas that are dark when seen from the warm side and light when seen from the cool side.

B.2.4 Other Thermal Patterns - Irregular variations of thermal patterns in the spaces between framing may be from a combination of possible causes including varying density of insulation, convection or air leakage, moisture, or thermal bridges. The following is a partial list of possibilities:

B.2.4.1 Varying density of insulation often allows air leakage or convection, creating intruding areas of surface temperature variation.

B.2.4.2 Insulation containing significant amounts of moisture conducts heat much better than dry insulation, or areas of no insulation. Within the moist areas, there may be a mottled and diffused thermal pattern, but without extremes because the moisture results in greater transverse

diffusion of heat.

B.2.4.3 Thermal bridges may be caused by the presence of fasteners or structural members.

B.2.4.4 Air leakage, usually at joints or junctions in the building envelope, typically produces irregular shaped patterns with uneven boundaries and large temperature variations. Air leakage can be detected thermographically when air of a different temperature than the viewed surface comes from the side of the envelope opposite the observer.

B.2.4.5 Indoor temperatures may vary from room to room, resulting in large areas appearing brighter than others as seen in an exterior survey. Independent verification of indoor temperatures can determine if the pattern is because of differences in temperature, or quality of the envelope.

B.2.4.6 If an object is removed from a surface, it may leave a thermal signature where it insulated the surface. The signature fades with time as the surface is allowed to achieve equilibrium.

B.3 If possible, the cause of thermal anomalies should be determined. This may be accomplished by analytical methods, ancillary measurements, interpretation experience, or by comparing the thermogram with reference thermograms for structures with known anomalies.

Appendix C

Aerial Roof Surveys

C.1 Survey Classes. ANSI/ASHRAE (1981) STANDARD 101-1981 defines two types of airborne standards: Class A and Class B as differentiated by the degree of resolution required. Class A is a high resolution survey and Class B a lower resolution survey. These are defined in terms of object plane resolution (pixel footprint on the roof of interest). A Class A survey shall have object plane resolution at the flight path nadir, no larger than 0.5 m. A class B survey shall have object plane resolution at the flight path nadir, no larger than 1.0 m. Under no circumstances shall resolution be greater than 1.0 m. In either case, interpretation is by comparison within a single roof structure.

C.2 Instrumentation. These surveys are usually performed using high-speed thermal IR line scanners where the movement of the aircraft over the ground sweeps the linear detector array over a strip-shaped FOV. However, this does not preclude using a two-dimensional imaging instrument, resulting in video formatted imagery.

C.2.1 Sensitivity. Required airborne survey instrument sensitivity is a function of windspeed and ΔT . The requirement is summarized in the AIRBORNE INSTRUMENT SENSITIVITY REQUIREMENT plot in Appendix F.

C.2.2 FOV. FOV shall be no greater than 90°. If the instrument FOV is greater than 90°, the only valid part for analysis will be that part of each image within the limits of $\pm 45^\circ$ from the flight path nadir.

C.2.3 Blackbody Reference. It is desirable that the sensor system incorporate a blackbody reference and appropriate signal processing to provide apparent radiance rather than radiance difference.

C.2.4 Automatic Gain. Automatic gain systems are not recommended because important signatures can be masked by gain changes.

C.2.5 Display. A display should be provided so that the operator can view the thermal map during data acquisition.

C.2.6 Data Recording. Data recording is described in Section 7.13.1 of this procedure.

C.2.7 FAA Compliance. Apparatus must comply with FAA regulations.

C.3 Aircraft Motion

C.3.1 Speed. Aircraft speed should be limited to ensure that continuous coverage results. This normally presents no problem for a two-dimensional video rate imager because at 30 video frames per second, the speed limitation, even at the low altitude required for adequate resolution, is of the order of Mach 10. However, since the instantaneous FOV of a linear detector array parallel to the flightpath can be very small, this could be an issue for relatively slow arrays.

C.3.2 Stability The thermal imagery should not be significantly degraded because of aircraft stability, which suggests scheduling a survey to coincide with anticipated calm periods.

C.4 Conditions During a Survey.

C.4.1 Buildings Buildings shall be heated during a survey, and roofs shall be clear of water, dew, snow, or ice.

C.4.2 Ambient Temperature The outdoor ambient temperature at ground level shall be at least 22°C below the building interior air temperature, unless the survey is conducted under a clear sky. In this case, a ΔT of 17°C is adequate. However, in all cases, it is preferable that the outside ambient air temperature not exceed 7°C.

C.4.3 Time of Survey The survey shall be conducted at least four hours after sunset and before sunrise.

C.4.4 Sky Conditions The sky conditions shall be homogeneous (clear or solid overcast) to permit uniform radiation transfer to occur.

C.4.5 Wind Speed Wind speed shall be no greater than 6.7 m/s at the nearest first or second order weather station, unless the purpose of the survey is to measure the performance of the building envelope at higher wind speeds.

C.5 Data to be Recorded The following conditions shall be recorded in a data log that shall be appended to the test report. Use of a log sheet form is suggested (see Appendix D).

C.5.1 Environmental Conditions Date, time, and general weather conditions (temperature, sky conditions, wind) shall be recorded during the survey. Significant changes during the survey should be noted.

C.5.2 Site Conditions A description of the survey site shall be included in the log, which should describe general terrain, topographic features, foliage, and the general nature of the structures being surveyed.

C.5.3 Equipment Conditions Equipment designation and serial number; fixed gain and contrast settings, if applicable; recorded temperature range; blackbody settings, if applicable, shall be recorded in the log. Significant changes during the survey shall be noted.

C.5.4 Flight Conditions Record flight line and orientation; approximate ground speed; and altitude in the log. Significant changes during the survey shall be noted.

C.6 Interpretation of Data Data collection from airborne thermographic surveys are not recommended for determination of R or U values, and do not provide conclusive information regarding probable causes of heat loss. However, they can document apparent radiance differences, allowing for a comparison of different areas of the same roof to identify potential thermal anomalies. These differences provide a preliminary identification of areas that should be further investigated. Comparison between different roofs may be misleading without incorporating information regarding surface differences, ambient condition differences, and instrumentation differences present during the survey.

C.7 Reporting. Reporting should follow Section 7.15 of this procedure, with the addition of flight conditions and flight line parameters. Interpretation and recommendations should include the caution that these thermograms can easily be misinterpreted if the interpreter is not experienced in thermogram interpretation.

Date Issued:
September 1993

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C.3

Mobile Energy Laboratory Procedure 10.0, Appendix C
Infrared Thermography, Version 1

Appendix D

Exterior Survey Form

NAME _____ DATE OF REPORT _____

SURVEY NUMBER _____ CLIENT _____

PROJECT _____

PO NUMBER _____ POC _____

EQUIPMENT: Inframetrics Model 800 _____ CALIBRATION DATE _____

CALIBRATION DATE _____

CALIBRATION DATE _____

EXCEPTIONS TO CALIBRATION _____

OTHER: B&W video camera, color monitor, B&W monitor, two VCRs

TYPE AND CLASS OF SURVEY _____

I hereby certify that the above listed project was performed by me under my direction, and that the attached images, data, analysis, and results are the result of this work.

SIGNED _____ DATE _____

PRINT NAME LEGIBLY _____

GENERAL CONDITIONS

DATE OF SURVEY _____ WIND SPEED _____ WIND DIRECTION _____

TIME OF DAY _____ INTERIOR AIR TEMP _____ EXTERIOR AIR TEMP _____

SKY CONDITIONS: CLEAR; CLOUDY; OVERCAST; MOON;

PRECIPITATION: RAIN; SLEET; SNOW; AMT LAST 24 HRS. _____

EXTERIOR WALL CONSTRUCTION

wood frame

masonry

wood siding

metal siding

brick veneer

other _____

ROOF CONSTRUCTION

wood frame/gable

concrete deck/slip

metal deck/lean-to

shingle ventilated attic

built-up flat roof/a) natural

other _____ b) power

HEATING SYSTEM

forced air

controls:

hot water

a) central

steam

b) zones

resistance electric c) room by room

other _____

HEATING DISTRIBUTION SYSTEM

radiator/grill or register at:

unit ventilator/a) floor

convector:b) low wall

a) wall/c) high wall

b) baseboard/d) in ceiling

other _____

COMMENTS _____

Date Issued:
September 1993

Supersedes Issue Dated:

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D.1

Mobile Energy Laboratory Procedure 10.0, Appendix D
Infrared Thermography, Version 1

Appendix D

Interior Survey Form

NAME _____ DATE OF REPORT _____

SURVEY NUMBER _____ CLIENT _____

PROJECT _____

PO NUMBER _____ POC _____

EQUIPMENT: Inframetrics Model 800 _____ CALIBRATION DATE _____

CALIBRATION DATE _____

CALIBRATION DATE _____

EXCEPTIONS TO CALIBRATION _____

OTHER: B&W video camera, color monitor, B&W monitor, two VCRs

TYPE AND CLASS OF SURVEY _____

I hereby certify that the above listed project was performed by me under my direction, and that the attached images, data, analysis, and results are the result of this work.

SIGNED _____ DATE _____

PRINT NAME LEGIBLY _____

GENERAL CONDITIONS

DATE OF SURVEY _____ WIND SPEED _____ WIND DIRECTION _____

TIME OF DAY _____ INTERIOR AIR TEMP _____ EXTERIOR AIR TEMP _____

SKY CONDITIONS: CLEAR; CLOUDY; OVERCAST; MOON;

PRECIPITATION: RAIN; SLEET; SNOW; AMT LAST 24 HRS. _____

EXTERIOR WALL CONSTRUCTION

wood frame

masonry

wood siding

metal siding

brick veneer

other _____

ROOF CONSTRUCTION

wood framegable

concrete deckhip

metal decklean-to

shingle ventilated attic

built-up flat roof a) natural

other _____ b) power

HEATING SYSTEM

forced air

controls:

hot water

a) central

steam

b) zones

resistance electric

c) room by room

other _____

HEATING DISTRIBUTION SYSTEM

radiatorgrill or register at:

unit ventilator a) floor

convector: b) low wall

a) wall c) high wall

b) baseboard d) in ceiling

other _____

COMMENTS _____

RAW IMAGE NUMBER	THERMOGRAM NUMBER
1	1
2	2
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100	100

ROOM _____

FLOOR _____
CEILING _____
WALL (N/E/S/W) _____

NUMBER OF WINDOW PANES/SIZE

THERMOGRAM NUMBER

[illegible]

INDOOR SURFACE TEMPERATURE: WALL _____ ROOF _____

ANALYSIS

[illegible]

Appendix D

Aerial Roof Survey Form

NAME _____ DATE OF REPORT _____
SURVEY NUMBER _____ CLIENT _____
PROJECT _____
PO NUMBER _____ POC _____
EQUIPMENT: Inframetrics Model 600 _____
CALIBRATION DATE _____
CALIBRATION DATE _____
CALIBRATION DATE _____

EXCEPTIONS TO CALIBRATION

OTHER: B&W video camera, color monitor, B&W monitor, two VCRs

TYPE AND CLASS OF SURVEY

I hereby certify that the above listed project was performed by me under my direction, and that the attached images, data, analysis, and results are the result of this work.

SIGNED _____ DATE _____

PRINT NAME LEGIBLY _____

AIRCRAFT/FLIGHT LINE PARAMETERS

PILOT _____ AIRCRAFT _____

DATE OF SURVEY _____ WIND SPEED _____ WIND DIRECTION _____

FLIGHT LINE:

START (LAT/LONG) _____ END (LAT/LONG) _____

DEVIATIONS _____

ALTITUDE (AMSL) _____ DEVIATIONS _____

SKY CONDITIONS: CLEAR; CLOUDY; OVERCAST; MOON

PRECIPITATION: RAIN; SLEET; SNOW; AMT LAST 24 HRS. _____

CONSTRUCTION CONDITIONS

INTERIOR AIR TEMP _____ EXTERIOR AIR TEMP _____

ROOF CONSTRUCTION

wood frame	gable
concrete deck	hip
metal deck	lean-to
shingle	ventilated attic
built-up flat roof	a) natural
other _____	b) power

COMMENTS _____

Appendix E

Preferred Conditions for Surveys

- E.1 Because of the thermal inertia, particularly of insulated envelopes, IR inspection requires a sufficiently large ΔT for a long period of time to produce a clearly detectable temperature anomaly. The preferred measurement of ΔT is surface to surface to eliminate potential solar and wind interferences.
- E.2 A minimum ΔT of 10°C between interior and exterior surfaces is suggested for a period of four hours prior to the start of a survey.
- E.3 If surface temperature measurements cannot be made, air-to-air temperatures may be used to define ΔT if the following precautions are taken.
- E.3.1 Shield the surface to be inspected from solar radiation for a period of approximately three hours prior to the inspection for light frame construction, and eight hours for masonry veneer construction. For ΔT greater than 10°C, these times can be reduced. For best results, exterior surveys should be performed during the period from sunset to sunrise.
- E.3.2 For exterior surveys, wind speed should be less than 6.7 m/s (15 mph).
- E.4 Building surfaces should be dry.
- E.5 Although the above conditions are recommended, it is possible to deviate from these recommendations if sufficient knowledge is applied to interpreting results. For example, solar heated surfaces may reveal anomalies in reverse contrast - the exterior surface may be cooler than the interior, resulting in cool anomalies against warm surroundings. Interior surveys may be possible in rooms below an attic for one to two hours after sunrise.

Appendix F

Figure F.1 System Performance Dependence on Wind

Instrument Sensitivity Requirements R0.35/R1.76 (R2/R10) Recognition @ 8-14 μm

Instrument Sensitivity Requirements R0.88/2.64 (R5/R15) Recognition @ 8-14 μm

Airborne Instrument Sensitivity Requirements

11.0 References

American Society for Testing Materials (ASTM). 1990. *Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings*. ASTM C 1060-90 Standard, Philadelphia, Pennsylvania.

American Society of Mechanical Engineers (ASME). 1974. *Power Test Code Steam Generating Units*. PTC 4.1-1974, New York.

American Society of Heating, Refrigeration, and Air-Conditioning Engineers, Inc. (ASHRAE). 1981. *Application of Infrared Sensing Devices to the Assessment of Building Heat Loss Characteristics*. ANSI/ASHRAE Standard 101-1981, Atlanta, Georgia.

Illuminating Engineering Society of North America (IES). 1984. *IES Lighting Handbook, 1984 Reference Volume*. New York.

Illuminating Engineering Society of North America (IES). 1987. *IES Lighting Handbook, 1987 Application Volume*. New York.

Illuminating Engineering Society of North America (IES). 1989. *IES Lighting Ready Reference*. New York.

Inframetrics, Inc. 1989. *Inframetrics Model 600L IR Imaging Radiometer Operator's Manual*. Waltham, Massachusetts.

Infraspection Institute. 1988. *Guidelines for Specifying and Performing Infrared Inspections*. Shelburne, Vermont.

Pacific Northwest Laboratory (PNL). 1989. *The Mobile Energy Laboratory Use Plan*. PNL-6861, Richland, Washington.

Statham Division of Solartron Transducers. *Gould PG3000 Series Instruction Manual*. Oxnard, California.

U.S. Executive Office of the President (EOP), Office of Management and Budget. 1987. *Standard Industrial Classification Manual*. National Technical Information Service (NTIS), Springfield, Virginia.

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