ASME EA-1–2009

Energy Assessment for Process Heating Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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This Standard will be revised when the Society approves the issuance of a new edition. There will be no addenda issued to this edition.

ASME issues written replies to inquiries concerning interpretations of technical aspects of this Standard. Periodically certain actions of the ASME EA Committee may be published as Cases. Cases and interpretations are published on the ASME Web site under the Committee Pages at http://cstools.asme.org as they are issued.

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FOREWORD

This document provides a standardized framework for conducting an energy assessment for process heating systems, hereafter referenced as an "assessment." A process heating system is defined as a group (or a set or combination) of heating equipment used for heating materials used in production of goods in an industrial plant. Assessments involve collecting and analyzing information on system design, operation, energy use, and performance data and identifying energy efficiency improvement opportunities to optimize system energy use or performance. An assessment may also include additional information, such as recommendations for improving resource utilization, reducing per unit production cost, reducing lifecycle costs, and improving environmental performance related to the assessed system(s).

This Standard provides a common definition for what constitutes an assessment for both users and providers of assessment services. The objective is to provide clarity for those types of services that have been variously described as energy assessments, energy audits, energy surveys, and energy studies. In all cases, systems (energy-using logical groups of industrial equipment organized to perform a specific function) are analyzed through various techniques, such as measurement and analysis, resulting in the identification, documentation, and prioritization of energy performance improvement opportunities.

This Standard sets the requirements for conducting and reporting the results of an assessment that considers the entire system, from energy inputs to the work performed as the result of these inputs. An assessment meeting this Standard need not address each individual system component or subsystem within an industrial facility with equal weight; however, it shall be sufficiently comprehensive to identify the major energy efficiency opportunities for improving the overall energy performance of the facility. This Standard is designed to be applied primarily at industrial facilities, but many of the concepts can be used in other facilities, such as those in the institutional and commercial sectors.

The Standard is part of a portfolio of documents and other efforts designed to assist in improving the efficiency of industrial facilities. Initially, four assessment standards are being developed for compressed air, process heating, pumping, and steam systems. Other related existing and planned efforts to improve the efficiency of industrial facilities include

(a) ASME guidance documents for the assessment standards, which provide technical background and application details to support understanding of the assessment standards. These guidance documents provide rationale for the technical requirements of the assessment standards and give technical guidance, application notes, alternate approaches, tips, techniques, and rules-of-thumb.

(b) A certification program for each ASME assessment standard that recognizes certified practitioners as individuals who have demonstrated, via a professional qualifying exam, that they have the necessary knowledge and skills to properly apply the assessment standard.

(c) An energy management standard, "A Management System for Energy, ANSI/MSE 2000:2008," which is a standardized approach to managing energy supply, demand, reliability, purchase, storage, use, and disposal and is used to control and reduce an organization's energy costs and energy-related environmental impact. NOTE: This ANSI standard will eventually be superseded by ISO 50001, now under development.

(d) An ANSI-accredited measurement and verification protocol that includes methodologies for verifying the results of energy efficiency projects.

(e) A program, Superior Energy Performance, that will offer ANSI-accredited certification for energy efficiency through application of ANSI/MSE 2000:2008 and documentation of a specified improvement in energy performance using the ANSI measurement and verification protocol.

The complementary documents described above, when used together, will assist organizations seeking to establish and implement company- or site-wide energy plans.

ASME EA-1-2009 was approved by the EA Industrial System Energy Assessment Standards Committee on October 1, 2009 and approved by the American National Standards Institute (ANSI) on December 2, 2009.

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(The following is the roster of the Committee at the time of approval of this Standard.)

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions, and attending Committee meetings. Correspondence should be addressed to:

Secretary, EA Committee
The American Society of Mechanical Engineers
Three Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

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The request for interpretation should be clear and unambiguous. It is further recommended that the inquirer submit his request in the following format:

Subject: Cite the applicable paragraph number(s) and a concise description

Edition: Cite the applicable edition of the Standard for which the interpretation is being requested.

Question: Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. The inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in this format will be rewritten in this format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME Committee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

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ENERGY ASSESSMENT FOR PROCESS HEATING SYSTEMS

1 SCOPE AND INTRODUCTION

1.1 Scope

This Standard covers process heating systems that are defined as a group (or a set or combination) of heating equipment used for heating materials in the production of goods in an industrial plant. These systems, commonly referred to using terms such as furnaces, melters, ovens, and heaters, use heat sources such as fuels, electricity, steam, or other fluids to supply the required heat.

This Standard sets the requirements for conducting and reporting the results of a process heating energy assessment (hereafter referred to as an "assessment") that considers the entire system, from energy inputs to the work performed as the result of these inputs. An assessment complying with this Standard need not address each individual system component or specific system within an industrial facility with equal weight; however, it shall be sufficiently comprehensive to identify the major energy efficiency opportunities for improving the overall energy performance of the system. This Standard is designed to be applied primarily at industrial facilities, but many of the concepts can be used in other facilities, such as those in the institutional and commercial sectors.

Assessments involve collecting and analyzing data on system design, operation, energy use, and performance and identifying energy performance improvements. An assessment may also include recommendations for improving resource utilization, reducing per unit production cost, reducing lifecycle costs, and improving environmental performance related to the assessed system(s). Assessment activities shall include, but are not limited to, engaging facility personnel and providing information about the assessment process; collecting and analyzing data on system design, operation, energy use, and performance; and identifying energy performance improvement opportunities and making recommendations in a written report. This report shall document system design; quantify energy operation and performance data; document the assessment process; show results, recommendations, and savings projections; and improve facility personnel's understanding of system energy use and operation.

This Standard sets requirements for

(a) organizing and conducting a process heating assessment

(b) analyzing the data from the assessment

(c) reporting and documentation of assessment findings

When contracting for assessment services, plant personnel may use the Standard to define and communicate their desired scope of assessment activity to third party contractors or consultants.

1.2 Limitations

This Standard does not provide guidance on how to perform a process heating system assessment but sets the requirements that need to be performed during the system assessment. For additional assistance, see the companion ASME Guide for ASME EA-1-2009 Energy Assessment for Process Heating Systems on how to apply this Standard.

(a) This Standard does not specify how to design a process heating system.

(b) This Standard does not specify the qualifications and expertise required of the person using the Standard.

(c) This Standard does not specify how to implement the recommendations developed during the assessment but does include recommendations for implementation activities.

(d) This Standard does not specify how to measure and validate the energy savings that result from implementing assessment recommendations.

(e) This Standard does not specify how to calibrate test equipment used during the assessment.

(f) This Standard does not specify how to estimate the implementation cost or conduct financial analysis for recommendations developed during the assessment.

(g) This Standard does not specify specific steps required for safe operation of equipment during the assessment. The plant personnel in charge of normal operation of the equipment are responsible for ensuring that it is operated safely during the data collection phase of the assessment.

(h) For outside individuals working in a private or publicly owned company facility, issues of intellectual property, confidentiality, and safety shall be addressed before beginning an assessment. While the importance of satisfying these requirements and related issues is acknowledged, they are not addressed in this Standard.

2 DEFINITIONS

assessment: activities undertaken to identify energy performance improvements in a process heating system that consider all components and functions, from energy inputs to the work performed as the result of these inputs. Individual components or subsystems might not be addressed with equal weight, but system assessments shall be sufficiently comprehensive to identify the major energy efficiency opportunities for improving overall system energy performance. System impact versus individual component characteristics should be discussed.

batch furnace: a furnace into which the entire work load is introduced periodically.

continuous furnace: a furnace into which the work load is introduced continuously or at short time intervals.

energy intensity (also called specific energy): the ratio of the energy used during a heating operation to the product unit or mass that absorbs the energy.

energy use baseline: amount of energy use measured during the operating conditions existing at the time of the assessment. It should be expressed in terms of energy per unit of production, energy per unit of mass or volume produced or in terms of energy per unit of time. Examples of the baseline units are: Btu/lb (kWh/kg), Btu/hr (kW), or Btu/unit of product (widget) or (kWh/unit of product).

functional requirement: description of what the plant expects the manufacturing system to do using the heating system. The parameters could be expressed in terms such as production output, quality (insofar as it can be controlled by the heating process), energy consumption (per production unit, if applicable), and emissions.

furnace: a term gener*ical*ly used in this Standard to describe process heating equipment, such as furnaces, melters, ovens, and heaters.

heat balance: a procedure in which an imaginary control boundary is placed around a process heating system and all energies and mass flows crossing that boundary are determined and summed.

maximum installed energy input rate: the maximum amount of energy that can be supplied, usually expressed in terms such as Btu/h, kW, kCal/h, kJ/h. In most cases, the maximum installed energy input rating can be obtained from the nameplate of the heating equipment, the operating manual, design drawings, or documents provided by the equipment supplier. In some cases, this is known as "connected heat input" or power rating.

maximum production capacity: maximum attainable or design production capacity expressed in terms such as lb/hr, tons/hr, and number of pieces per hour while operating the equipment in safe mode.

normal operating conditions: the conditions at which the heating system is operated for a majority of the time. Parameters such as production rate, operating temperatures and pressures, and load or charge conditions (e.g., temperature, moisture content) should be used as a guide to determine normal operating conditions.

process heating system: process heating system includes a group (or a set or combination) of heating equipment used to heat materials used in production of goods in an industrial plant. The system includes heating equipment, such as furnaces, melters, ovens, heaters.

resource utilization: use of available resources such as energy, money, material, and manpower to perform the necessary functions in plant operation.

Sankey diagram: specific type of flow diagram in which flows are represented by arrows. The width of the arrows is shown proportionally to the flow quantity. They are typically used to visualize energy or material transfers between processes.

thermal efficiency: for a particular process heating system, it is the ratio of the energy absorbed by the material being processed to the total energy consumed to heat the system.

3 REFERENCES

3.1 Reference Standards

There are no reference standards in this document.

3.2 Informative References

This Standard can be incorporated into an energy management plan developed using ANSI/MSE 2000:2008, A Management System for Energy, Georgia Institute of Technology, 2008. Nonmandatory Appendix A lists key references with additional information on process heating systems.

4 ORGANIZING THE ASSESSMENT

4.1 Identification of Assessment Team Members

A comprehensive and complete assessment can be achieved only when a set of knowledgeable personnel participates in the assessment process. Functions required to accomplish an assessment are listed in para. 4.1.1. The assessment team shall have members who are assigned responsibility and authority to carry out these functions.

4.1.1 Required Functions and Personnel

4.1.1.1 Resource Allocation

(a) Allocate funding and resources necessary to plan and execute the assessment.

(b) Exercise final decision-making authority on resources.

(c) Oversee the participation of outside personnel, including contracts, scheduling, confidentiality agreements, and statement of work.

4.1.1.2 Coordination, Logistics, and Communications

(a) Obtain necessary support from plant personnel and other individuals and organizations during the assessment.

(b) Participate in organizing the assessment team, and coordinate access to relevant personnel, systems, and equipment.

(c) Organize and schedule assessment activities.

4.1.1.3 Process Heating Systems Knowledge

(a) Have background, experience, and recognized abilities to perform the assessment activities, data analysis, and report preparation.

(b) Be familiar with operating and maintenance practices for process heating systems.

(c) Have experience applying the systems approach in assessments.

Information on other assessment team members is identified in para. 4.8.3.

4.2 Facility Management Support

Facility management support is essential for the successful outcome of the assessment. Facility management shall understand and support the purpose of the assessment. They shall allow assessment team members from the plant to participate in the assessment to the extent necessary. The assessment team shall gain written support of plant management prior to conducting the assessment, as follows:

(a) Commit the necessary funding, personnel, and resources to support the assessment.

(b) Communicate to facility personnel the assessment's importance to the organization.

4.3 Communications

Lines of communication required for the assessment shall be established. The assessment team shall provide clear guidance to facilitate communications among members of the assessment team so all necessary information and data can be communicated in a timely manner. This includes administrative data, and logistics information, as well as operational and maintenance data.

4.4 Access to Equipment, Resources, and Information

For the performance of a complete and comprehensive assessment of a facility's process heating system, it is necessary to physically inspect and make selected measurements on the system components. The assessment team shall have access to

(a) plant areas and process heating systems required to conduct the assessment

(b) plant personnel (engineering, operations, maintenance, etc.), their equipment vendors, contractors, and others, to collect information pertinent and useful to the assessment activities and analysis of data used for preparation of the report

(c) other information sources, such as drawings, manuals, test reports, historical utility bill information, computer monitoring and control data, control panels, and calibration records

4.5 Assessment Goals and Scope

The overall goals and scope of the assessment shall be discussed and agreed upon at an early stage by the assessment team. The overall goal of the assessment shall include identification of performance improvement opportunities in the process heating system being assessed and using a systems approach. The scope of the assessment shall define the portion(s) of the facility that are to be assessed.

4.6 Initial Data Collection and Evaluation

The following data shall be obtained for each of the process heating systems being evaluated:

(a) Type of energy (fuel, electricity, steam, etc.) used and power input ratings (when available) in terms of units, such as kW or Btu/h.

(b) Actual production throughputs and energy use of specific processes in terms of Btu, kCal, kJ, or kWh over a defined time interval (hour, shift, day, week, month, etc.) collected from individual equipment meters or other available resources. Where individual meters are not installed on the equipment, the process heating energy use information shall be collected at the plant level closest to the process heating equipment, if it is useful.

(c) Where individual meters are not available, energy use should be estimated by using information on operating hours, percentage of the installed or designed equipment heat input rate, and equipment up-time or load factor.

4.6.1 Initial Facility Specialist Interviews. The assessment team shall contact personnel and specialists within the plant to collect information on operating practices and any specific operating considerations that affect energy use for the equipment. This information shall be used to help develop the site-specific goals and assessment plan of action (paras. 4.7 and 4.8).

4.6.2 Energy Project History. The assessment team shall collect and review information on energy saving projects, assessments, audits, baselines, or benchmarking already conducted for the process heating system.

4.6.3 Primary Energy Cost. The cost data shall include values in terms of units such as cost per million Btu (MMBtu) or kWh, or other similar terms, considering all charges, such as purchased cost, transportation cost, demand charges, peak rates, time-of-the-day rate, and any other costs up to the point of use. Where necessary, appropriate costs should be assigned to by-product fuels and steam, on-site generated electricity or steam, and in-house generated utilities

(process gases, water, other fluids, etc.). These costs should be used in subsequent analyses. The assessment team shall agree on the period during which the costs would be considered valid. Although average values are appropriate in most cases, the assessment team should also consider issues such as demand charges and trends to identify situations not made obvious by the use of averages.

From this information, an average annual energy cost/ kWh (electric) or cost/MMBtu (fossil fuel if on-site generation is used) over the previous 12 mo, or another appropriate time period, shall be determined. A facility may have already established a marginal cost for energy that can be used.

4.7 Site-Specific Goals

The assessment team shall develop the assessment goals as they apply to the plant site. These goals should be consistent with the organizational goals for the process heating systems.

In the assessment plan of action, described in para. 4.8, the assessment team shall identify assessment objectives and action items that will contribute to achieving the assessment goals.

4.7.1 Preliminary Selection of Process Heating Systems for Assessment. The assessment team shall prepare a preliminary list of systems for the assessment. Selection shall be based on data and information collected in the activities described in paras. 4.6.1 through 4.6.3 and the priorities established by plant management.

The assessment team may divide the opportunities into three categories

(a) worthy of further analysis

(b) possible candidates for analysis after higher priority opportunities are dealt with

(c) unsuitable for assessment

The selection shall be based on factors such as energy use, applicability, past experience with application of the identified opportunities, effect on current and future operations, considerations for product quality, safety, and equipment life.

4.8 Assessment Plan of Action

An assessment plan of action shall be developed that includes the items discussed in paras. 4.8.1 through 4.8.5.

4.8.1 Definition of Data Collection Requirements and Methods

4.8.1.1 Measuring, Metering, and Diagnostic Equipment Required. The assessment team shall identify the instruments, data loggers, and other data collection equipment required for the assessment. This equipment shall be inspected and calibrated or repaired, if necessary, before the assessment to ensure reliable indications. The following list includes commonly used measuring and monitoring instruments:

(a) gas temperature-measuring instruments, such as thermocouples and thermometers

(b) flue gas analyzer with capability to measure oxygen (O_2), carbon monoxide (CO), and total hydrocarbons (HC)

(c) surface temperature measurement instruments, such as infrared pyrometers and contact thermocouples

(d) pressure-measuring instruments, such as pressure gages, digital or liquid-filled manometers, and draft gages

(e) voltmeters, ammeters, and wattmeters

(f) steam flow meters

(g) other special-purpose instruments as required

Additional instruments and measurement devices for specific purposes should be used, if required. The ranges of instrument measurement scales will depend on the operating parameters (e.g., temperature, pressures, flow) of the equipment. The assessment team shall define the range of measurement parameters expected during the assessment.

4.8.1.2 Definition of Data Collection Methods. The assessment team, in consultation with the appropriate plant personnel, shall define data collection methods for the selected equipment in a measurement plan. Options include measurements of the required operating parameters at selected locations on the equipment itself, data collection using permanently installed instruments on the equipment, data displayed on control panels or other locations such as computer screens, operating data provided by plant personnel and design data given in drawings, and operating instructions supplied by vendors. In each case, the measurement plan shall include details of the method of data collection, source of data, and measuring instruments used.

4.8.2 Initial Measurement Plan: Where and When to Collect Data. The assessment team shall prepare a measurement plan that describes and/or displays, for each piece of equipment

(a) a sketch of the equipment showing points where the measurements are to be taken and the test equipment to be used at those locations

(b) a list of measurements, types of instruments to be used, frequency, and timing of measurement (especially for batch operations or in cases where production and operating parameters change) to ensure true representation of average operating conditions

The plan should be discussed with the appropriate persons to ensure minimum adverse impact on production, product quality, etc. when the external instrumentation or data collection equipment is used. The plan should also include special requirements for the measurements, such as providing access ports at the required locations, installing sampling lines, and providing utility services required by the sensors and measuring instruments. The plan should also include a tentative schedule, work breakdown, and

personnel responsibility to ensure efficient data collection. The plan should include provision for independent verification of data, especially when it has been collected from permanently installed instruments or from control panels or displays. Verification requirements should be determined by the assessment team members' confidence in the measurement system used and/or their prior experience.

4.8.3 Identification of Other Assessment Team Members Required. The assessment team shall identify other members to participate in the assessment activities. The assessment team members should have knowledge of one or more aspects of process heating, such as

(a) manufacturing processes for which the heating systems are used

(b) design, controls, and instrumentation for the heating systems and equipment

(c) operating practices of the heating systems being assessed

(d) maintenance of subsystems or critical components, such as, but not limited to, burners or other types of heating systems, material handling system, equipment structure, and heat recovery equipment

(e) company goals, financial hurdles, company culture, and available capital

(f) access to at least several months of historical energy use and operating and technical data

Assessment team members shall be empowered to allocate the required time and resources as identified by the assessment plan of action.

4.8.4 Assessment Schedule. The assessment team shall prepare a schedule for the assessment activities. The schedule shall include a list of specific process heating devices to be assessed, times when the equipment will be available for data collection, and a list of the required data collection equipment and personnel. The following shall also be made available, as needed:

(a) safety briefing.

(b) nondisclosure agreements.

(c) liability insurance requirements.

(d) requirements for personal protective equipment. All assessment team members shall have the necessary equipment prior to the assessment.

It is essential to schedule the dates reserved for the assessment and to organize a set of scheduled events. For this reason, the dates of the assessment, and dates and times of key meetings, shall be designated in advance of beginning the assessment.

A meeting shall occur just prior to the commencement of the assessment. The purpose of this meeting is to review information collected in the preliminary data collection and evaluation and establish the work schedule. At this meeting, the assessment team should discuss the tools, methods, measurement, metering, and diagnostic equipment required. The assessment team should also establish the daily schedule(s) for the on-site assessment.

Periodic reporting to facility managers in the form of debriefings should occur as agreed upon by the assessment team. Also, irregularities may occur during an assessment (e.g., the failure of a computerized records system). If and when such events occur, the assessment team shall determine a corrective course of action.

The on-site assessment activities will conclude with a wrap-up meeting designed to outline the assessment investigations and initial recommendations. This meeting is discussed in para. 5.7.

4.8.5 Key Personnel Interviews. Subject to modification during the course of the assessment, the dates and times for the assessment team to meet with key plant or facility managers and process operators shall be specified and agreed upon by all individuals who will be participating in each meeting event. It shall be recognized that all data initially identified as essential to the assessment shall be obtained in discussions with knowledgeable facility staff.

4.9 Goal Check

Prior to conducting the assessment, the assessment team shall ensure that the plan of action meets the stated assessment goals. The assessment plan of action shall be reviewed for relevance, cost effectiveness, and capacity to produce the desired results.

5 CONDUCTING THE ASSESSMENT

The assessment team should follow the assessment activities shown in Fig. 1.

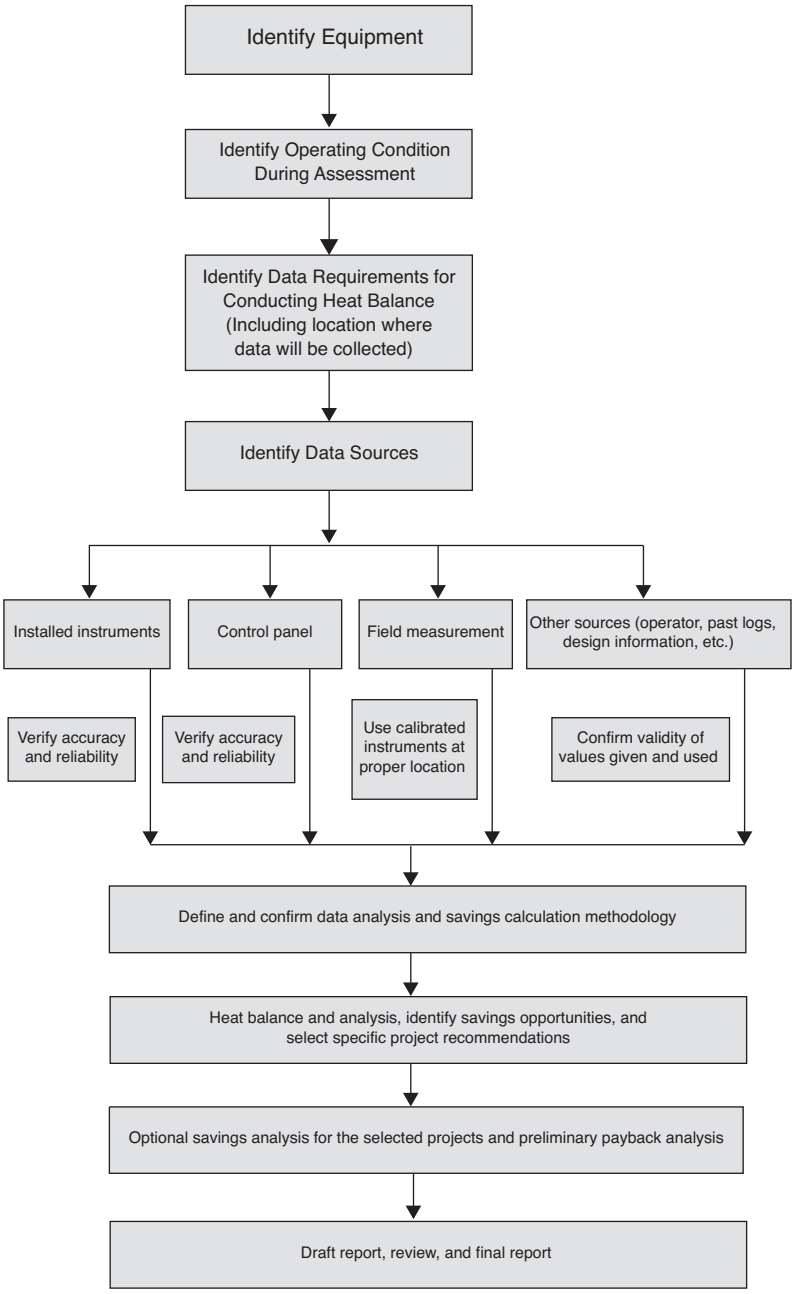
5.1 Establishing Data Collection Priorities

Requirements for the development of a preliminary list of process heating systems are detailed in para. 4.7.1. The requirements for data collection methods are detailed in para. 4.8.1. These should be reviewed and updated before conducting the assessment.

5.2 Determining the Functional Requirement of Each System

For each process heating system studied, the assessment team shall determine the system's functional requirements, such as production output, quality (insofar as it can be controlled by the heating process), energy consumption (per production unit, if applicable), and emissions. The assessment team should poll appropriate plant departments to develop a complete profile of expectations or use original design parameters as a guide. These might include parameters such as energy use per unit of product (energy intensity) and product yield.

Fig. 1 Assessment Activities



5.3 Review of Permanently Installed Meters

The team shall identify all the utility flow (e.g., fuels, oxygen) and electrical power meters permanently installed on process heating devices. As needed, they will obtain output data, if it has been recorded and preserved, for a period of time and in a format they deem appropriate. This may include input or production-related consumption data. The assessment team shall also confirm that the installation of the meters conforms to their manufacturers' recommendations for accurate operation and that they are properly calibrated per manufacturer's recommendations.

5.4 Identification of Control System and Strategy Used

For each process heating device or system assessed, the assessment team shall determine the type of control systems and strategies used. These shall include (where applicable), but are not limited to, control systems for

temperature, heat input, air-fuel ratio, furnace pressure or draft, atmosphere generation, and safety.

5.5 Identification of Operating and Maintenance Practices

The assessment team shall obtain information on operating and maintenance practices for the process heating devices covered by the assessment.

5.5.1 Operating data and information shall include, but not be limited to

(a) heating process cycles, production cycles, product throughput, and product mix

(b) operating parameters, such as temperatures, pressure (draft), and flue gas analysis (e.g., oxygen, carbon monoxide)

(c) frequency and duration of typical process interruptions due to factors outside the process heating system

(d) product- or production-related issues that impact how the heat processing operations are run

(e) product and process quality factors that must not be negatively impacted by a change in heat processing operations

(f) other operating parameters that are monitored regularly (e.g., Btu/lb of product), along with historical data on these parameters

5.5.2 Maintenance practices and data shall include, but not be limited to

(a) preventive maintenance and burner and combustion equipment tuning schedules. The assessment team shall verify these schedules are, in fact, observed in practice. If not, the assessment team shall determine what the practices actually are.

(b) instruments and test procedures used to monitor those operating parameters and procedures for and frequency of calibration.

(c) maintenance history, with particular attention paid to parameters and equipment requiring frequent corrective intervention.

(d) planned outage schedules and forced outage history.

5.6 Implementation of Measurement Plan (Data Collection)

The assessment team shall develop a measurement plan to ensure that data collected is accurate, repeatable, and reliable under the same operating conditions.

5.6.1 Identification of Data Collection Requirements. The assessment team shall identify the necessary data requirements for the heat balance and shall identify specific sources, such as preinstalled instruments, control panels, operator input, or additional measurement using instrumentation at specific locations.

The assessment team shall review the available data sources and data collected up to this point and determine what additional data are needed to conduct heat balances on the selected process heating equipment.

The assessment team shall prepare a worksheet that shows the required data, the most suitable source for that data, and method of validation, if required. This matrix shall be used to define the data collection activities. Example of a typical worksheet is shown in Fig. 2.

5.6.2 Determination of Data Collection Methods. Once the required data have been identified, the assessment team shall determine how it is collected. This shall require

Fig. 2 Example Worksheet

Name of the equipment _____

Operating conditions _____

Date _____ Time of data collection_____

Required Data	Source of the Data	Validation Method	Responsible Assessment Team Member	Remarks

(a) determination of the appropriate instruments to gather the data and ensure they are properly calibrated

(b) determination of the appropriate locations and installation procedure for data collection and the correct sampling equipment and procedures

(c) determining the appropriate times in the equipment operating cycle for data collection and the frequency of collection

5.6.3 Data Collection. Data collection duties shall be assigned to various members of the assessment team. Wherever possible, all data pertaining to a particular process heating device should be collected at the same time to ensure it is a "matched set."

The assessment team shall verify the instruments used for data collection are properly functioning, calibrated, and installed at proper locations within the system.

5.6.4 Data Review. Assessment team members shall review the collected data. The review process shall include cross-checking of data obtained from installed instrumentation or control panels with an independent source (direct or indirect) for the same data. Should any results appear inconsistent or in conflict with other data, the members shall collect a second set of data at the identical operating conditions to verify the original figures. If serious inconsistencies appear between the first and second sets, assessment team members shall review the sampling procedures, instrument calibration, and equipment operating modes at the times of the tests.

Data are considered acceptable only after assessment team members have determined the reasons for the inconsistencies and have corrected them. If the assessment team discovers any equipment or operating conditions that compromise safety or product or process performance, they shall report these issues immediately to plant management.

5.6.5 Process Heating System Baseline. To completely define assessment conditions, it is necessary to establish the system(s) baseline through gathering process heating energy use data and relevant production operating data. These data are the basis of future system performance comparisons. The assessment should record system operating conditions in a way that can be accessed in the future.

5.7 Wrap-Up Meeting and Presentation

As the final step in conducting the on-site part of the assessment, some or all members of the assessment team shall make a presentation of findings. This event shall be attended by all managers involved in and concerned with the assessment and all assessment team members. The presentation should include the assessment process used, review of the current status of process heating system energy efficiency, the tentative results of the assessment, the recommended assessment measures with energy, and approximate cost savings projections, if available. The results presented in this meeting shall be qualified as preliminary, subject to needed further analysis. The target dates for the delivery of a draft and final versions of the final written report shall be set by mutual agreement.

6 ANALYSIS OF DATA FROM THE ASSESSMENT

6.1 Introduction

The purpose of the analysis is to develop, for each heating device studied, an energy balance (and material balance, when appropriate) based on the collected data, to compare the results of this energy balance with industry-accepted benchmarks, determine areas where energy efficiency could be improved, identify ways this improvement could be obtained, and, as an optional activity, conduct a financial analysis of those suggested improvements.

6.2 System Data Analysis

The assessment team shall develop energy (heat) balances for the equipment evaluated during the assessment. Raw data collected during the assessment shall be used to calculate energy (heat) distribution for the system using manual calculations or software tools designed for the purpose. Where raw data are used to calculate components of the energy flow, such as wall heat losses from outside surface (skin) temperatures, accepted equations, graphs, or software shall be used to conduct these supporting calculations. These calculation methods and assumptions and their sources shall be clearly documented and described in the assessment report. The heat balance for each system assessed can be presented in the form of a table or chart that illustrates energy input and its distribution, including recycling of energy, if any, within the system.

For continuous processes, the heat balance should be presented in terms of energy flow per hour (e.g., Btu/h, kJ/h, kW, etc.). For batch processes, the heat balance should include energy flow in terms of quantity of energy (e.g., Btu, kJ, kWh, etc., per unit of production or for a specific duration or cycle time).

Data analysis results should include heat balances, energy intensity for the process equipment, and observations about equipment conditions (e.g., condition of insulation, openings, and areas of losses) not directly mentioned in the heat balance but which provide information on future energy savings opportunities.

6.3 Calculations and Identification of Specific Energy Savings Opportunities

The assessment team shall compare the output of the energy balance analyses (reported as overall energy consumption, energy intensity, or thermal efficiency)

to design values, accepted industry benchmarks, and/or targets established by plant management. Industry-accepted benchmarks, if used, should be defined and should be for identical or similar operating modes (e.g., batch vs. continuous, very large units vs. very small units) and similar types of equipment. This analysis, taking utility costs into account, identifies areas where energy savings opportunities exist and is critical to developing estimates of the savings resulting from taking advantage of those opportunities. Separating opportunities into categories based on the ease of implementation and cost of carrying them out may assist in establishing their priorities. These categories include maintenance improvements, operational improvements, equipment upgrades and replacement, revising control strategies and process improvements, changeovers, and others, as described in paras. 6.3.1 through 6.3.6.

6.3.1 Examples of Maintenance Improvements. Maintenance improvement opportunities often yield relatively high savings for the amount of time and money invested and often can be quickly implemented. They require efforts to restore the heating equipment to its original design specifications or enhance its performance with minimal or no capital investment. Examples include adjusting excess combustion air to more efficient levels, repairing door or access cover seals, repairing or recalibrating control instruments, patching or replacing deteriorated insulation, and developing preventive maintenance procedures.

6.3.2 Examples of Operational Improvements. Operational improvement opportunities deal with the way the heating equipment is operated in the production environment. Examples include rescheduling work flows to reduce idle time or temperature set point changes, minimizing overall energy consumption associated with restarts after idle production shifts, and altering workflow patterns or heating equipment locations to preserve thermal energy in products between processes. These changes shall not negatively affect process performance or product quality. Changing product quality requirements may be an appropriate way of saving energy or increasing throughput but only if approved by plant management.

6.3.3 Examples of Equipment Upgrades and Replacement. Equipment upgrade and replacement opportunities require capital investment to improve the thermal efficiency of the processing equipment. Typical upgrades include the addition of exhaust gas heat recovery to fuel-fired furnaces, replacement of heating elements or burners with higher performance designs, upgrades to fans and ductwork for higher heat transfer rates, and replacement of existing insulation with materials of higher thermal performance.

6.3.4 Examples of Revising Control Strategies. Revised control strategy opportunities deal with the way in which the output of the device's heating system is regulated. In some cases, they may simply require reconfiguring of existing controls. In others, they will require replacement of existing control systems and components. They include changing the location or type of temperature sensors, replacing electromechanical contactors with silicon-controlled rectifiers (SCRs), converting from two-position to proportional temperature controls, and revising heating zone temperature profiles. Some of these revisions can be implemented quickly and may yield significant savings for a modest investment of time and money.

6.3.5 Examples of Process Improvements/Changeovers. Process improvement and changeover opportunities require additional detailed study because they embody fundamental changes to the product and/or its processing to reduce the energy required to make it. Such opportunities might include changing the material of a product to permit a less energy-intensive thermal treatment or to eliminate heat processing altogether.

6.3.6 Examples of Other Energy Savings Opportunities. Other opportunities include all other methods not considered above. One example is fuel switching. This may include conversion of electrical heating systems to fuel fired systems, fuel fired systems to electrical heating systems, use of by-product fuels, or use of a hybrid system where more than one energy source is used for processing the product.

6.4 Energy Use Baseline

The assessment shall define and develop an energy use baseline for the process heating system(s). The baseline can be in terms of units such as energy used per unit of production, per unit of time, or other appropriate units that can be used for future comparison after implementation of energy efficiency improvement projects.

6.5 Technical and Financial Analysis

The assessment team, in cooperation with other resources, shall carry out a technical analysis for the energy savings opportunities identified for the various heating systems. Technical analysis should include considerations for issues, such as availability, performance, acceptability, and history. A list of selected and unselected opportunities, with reasons for the decision, shall be documented in the reviews as well as the final report.

Recommendations not meeting the technical criteria established by the plant personnel or leadership staff shall be separated from those that are acceptable.

A financial analysis, as an optional activity, should be carried out for the technically acceptable recommendations and shall include net savings (economic benefits) and estimates of budgetary cost for implementation of each

of the recommendations. Net savings shall include all appropriate components, such as energy cost, productivity changes, labor costs, improved product quality, maintenance cost savings, and emission reduction. Implementation costs shall include all appropriate components, such as hardware, installation labor, and start-up costs. These should be obtained using various resources, such as the assessment team experience.

The analyses shall categorize the opportunities, according to the plant's chosen method of evaluation, or as operating, maintenance, capital, or other specially funded projects. For capital projects, a financial justification like a simple payback analysis or internal rate of return shall be prepared if a financial analysis is completed.

Plant or corporate financial personnel should be contacted for guidance on the requirements and specific methodology to use.

Methods used for the implementation cost estimate, data sources, and implementation costs shall be clearly noted in the assessment report.

7 REPORTING AND DOCUMENTATION

7.1 Final Assessment Report

At the conclusion of the on-site assessment and any required follow-up data analysis, the assessment results shall be reported in a final written report, as described in para. 7.2.

7.2 Final Assessment Report Contents

The final assessment report shall include the following information:

(a) executive summary
(b) facility information
(c) assessment goals and scope
(d) description of system(s) studied in assessment and significant system issues
(e) assessment data collection and measurements
(f) data analysis
(g) energy use baseline
(h) performance improvement opportunities and prioritization
(i) recommendations for implementation activities
(j) appendices

7.2.1 Executive Summary. This section shall condense and summarize the report in brief. The executive summary shall provide an overview of

(a) the facility, plant background, and products made at the plant
(b) goals and scope of the assessment
(c) system(s) assessed and measurement boundaries used
(d) energy use baseline
(e) performance opportunities identified with associated energy and cost savings
(f) recommendations for implementation activities

7.2.2 Facility Information. A detailed description of the facility, plant background, and products made at the plant shall be included in this section.

7.2.3 Assessment Goals and Scope. This report section shall contain a brief statement of the assessment's goals. The report shall identify the boundaries of the specific system(s) on which the assessment was performed and why the boundaries were selected. This report section shall include a description of the general approach and methodology used to conduct the assessment.

7.2.4 Description of System(s) Studied and Significant System Issues. The report shall include a detailed description of the specific system(s) on which the assessment was performed. Descriptions shall include major characteristics of the equipment, such as type of device, operating method (e.g., batch, continuous, semi-batch), products processed, production capacity, type of heat source used, and maximum heat consumption. Any special product considerations bearing on system or process alterations shall be noted. Depending on the system assessed, the discussion of system operation can be extensive and should be supported by graphs, tables, and system schematics. Supporting documentation should also be included to clarify the operation of the system components and their interrelationships.

Any significant system issues related to energy use and others affecting the energy use shall be described, including an operational review of system. Any existing best practices found (methods and procedures found to be most effective at energy reduction) shall be documented.

7.2.5 Assessment Data Collection and Measurements. The methods used to obtain data and conduct measurements shall be identified, including an overview of the measurement plan. Measurement data and observations required for para. 7.3 not reported in para. 7.2.6 shall be placed in an appendix. This report section shall also include, for each heating system studied, the highlights of the energy flows represented in form of tables, graphs, or commonly used methods, such as Sankey diagrams. Where information is available, that performance shall be compared with design values, industry or corporate benchmarks, or other similar units used within the plant or other plants of the company. Significant factors contributing to that performance shall be described, along with any other particularly noteworthy findings.

This report section shall also identify the methods, models, or software used for analysis and the results they produced.

Raw data, such as flue gas measurements and furnace wall losses, the instruments and methods used to collect them, and energy balances and their supporting calculations, shall reside in the report appendix. Data shall be reported in units customarily used by the plant.

The assessment report should give details on the consistency, repeatability, and reproducibility of the measurements. The assessment report should show the confidence, precision, and data loss of measurements.

7.2.6 Data Analysis. The report shall include the outcome of the measurements and data analysis in accordance with the site-specific assessment goals, assessment plan of action, and statement of work. Any significant analytical methods, measurements, observations, and results from data analysis from completed action items shall be documented.

7.2.7 Energy Use Baseline. The assessment report shall contain the energy use baseline for the process heating system(s). The analytic method used to develop the energy use baseline and units of the baseline shall be described. Plant functional and production process observations and information shall be reported.

The report shall clearly describe the process heating system energy use baseline. This baseline can be adjusted for changes in operating conditions.

7.2.8 Performance Improvement Opportunities Identified and Prioritization. The analysis shall quantify estimates of energy reduction and energy cost savings from recommended performance improvement opportunities. The report section shall include a list and description of significant contingent benefits, such as reduced emissions, increased productivity, and lowered energy cost per unit of production. Additional calculations may address other energy and non-energy benefits. The report shall identify the methods of calculation and software models used with assumptions clearly stated.

Performance improvement opportunities can include those from maintenance improvements, operational improvements, equipment upgrades and replacement, revising control strategies, process improvements and change-over, and other actions that reduce energy consumption.

Details on performance improvement opportunities to be documented and reported shall include a sufficiently detailed description of the actions required for project implementation. To aid in the selection of projects for implementation, the assessment team should categorize the opportunities as high, medium, or low priority based on factors such as

(a) energy and cost savings
(b) likelihood of achieving projected savings
(c) likelihood of long project life with sustained savings
(d) impact to ongoing operations
(e) changes or modifications necessary for the existing equipment
(f) time and cost for implementation
(g) complexity of implementation steps
(h) potential parallel benefits (e.g., improved profitability, improved operations, lower environmental impact)

7.2.9 Recommendations for Implementation Activities. The report should include a description of steps needed to implement the opportunities identified during the assessment. Methods for refining data analysis as needed and for obtaining reliable implementation cost estimates should be addressed. Steps for optimizing and maintaining system performance following implementation of adopted measures should be identified.

Implementation cost estimates for the performance improvement opportunities, if developed as an optional activity, are intended to be in metrics, such as return on investment and payback period.

The recommendations may include the need for further engineering analyses prior to implementing the identified assessment opportunities.

7.2.10 Appendices. Material that is somewhat lengthy and does not necessarily contribute to the overall presentation of the report should be included in appendices to keep the body of the report short.

This section shall include one or more of the following topics with appropriate details that allow the reader to fully understand the assessment process, data analysis, and basis for the recommendations. Topics may include details of process heating equipment, energy sources and their use during operations, instrumentation and data sources used for the energy balance, and computational tools, including software or other calculation methods used.

7.3 Data for Third Party Review

The report or other documentation delivered with the report shall include sufficient raw data from the assessment so that the analyses performed in section 5 can be confirmed by a third party. This documentation shall be structured so it can be easily accessed by verifiers and other persons not involved in its development.

7.4 Review of Final Report by Assessment Team Members

Before the assessment report is finalized, members of the assessment team shall review the assessment report for accuracy and completeness and provide comments. Upon review of the draft report and requests for modifications, the assessment team shall provide a consensus acceptance and then prepare and issue the report in final form.

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NONMANDATORY APPENDIX A
KEY REFERENCES

A-1 REFERENCES

Reed, R., 1986, *North American Combustion Handbook*, Vols. I and II, North American Mfg. Co., Cleveland, OH 44105.

Baukal, C., Jr., 2001, *The John Zink Combustion Handbook*, CRC Press, New York, NY.

Industrial Heating Equipment Association, 1994, *Combustion Technology Manual*, Industrial Heating Equipment Association, Cincinnati, OH.

Trinks, W., Mawhinney, M. H., Shannon, R. A., Reed, R. J., and Garvey, J. R., 2004, *Industrial Furnaces*, John Wiley & Sons, Inc., Hoboken, NJ.

The U.S. Department of Energy, 2005, *Improving Process Heating System Performance: A Sourcebook for Industry*, The U.S. Department of Energy, Washington D.C.

A-2 SOFTWARE TOOLS FOR PROCESS HEATING AND RELATED TOPICS

The following software tools are available for download on the U.S. Department of Energy Web site www.eere.energy.gov/industry under the section "Software Tools."

Process Heating Assessment and Survey Tool (PHAST)
Combined Heat and Power Application Tool (CHP)
NOx and Energy Assessment Tool (NxEAT)
Steam System Scoping Tool
Steam System Assessment Tool (SSAT)
3E Plus

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