ASME EA-1G–2010

(ANSI Designation: ASME TR EA-1G–2010)

Guidance for ASME EA-1, Energy Assessment for Process Heating Systems

AN ASME TECHNICAL REPORT

ASME

SETTING THE STANDARD

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Guidance for ASME EA-1, Energy Assessment for Process Heating Systems

A TECHNICAL REPORT PREPARED BY ASME AND REGISTERED WITH ANSI

ASME SETTING THE STANDARD

Three Park Avenue • New York, NY • 10016 USA

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This Guide will be revised when the Society approves the issuance of a new edition. There will be no addenda or written interpretations of the requirements of this Guide issued to this edition.

The American Society of Mechanical Engineers
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Nonmandatory Appendices

FOREWORD

This guidance document provides technical background and application details in support of the understanding and application of ASME EA-1, Energy Assessment for Process Heating Systems. This document provides background and supporting information to assist in applying the standard. The guidance document covers such topics as rationale for the technical requirements of the assessment standard; technical guidance, application notes, alternative approaches, tips, techniques, and rules-of-thumb; and example results from fulfilling the requirements of the assessment standard. This guidance document was developed to be used as an application guide on how to utilize ASME EA-1.

ASME EA-1 provides a standardized framework for conducting an assessment of process heating systems. 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 performed using the requirements set by ASME EA-1 involve collecting and analyzing system design, operation, energy use, and performance data and identifying energy performance improvement opportunities for system optimization. These assessments may also include additional information, such as recommendations for improving resource utilization, reducing per unit production cost, reducing life cycle costs, and improving environmental performance of the assessed system(s).

ASME EA-1 provides a common definition for what constitutes an assessment for both users and providers of assessment services. The objective is to provide clarity for these 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, resulting in the identification, documentation, and prioritization of energy performance improvement opportunities.

This guide is part of a portfolio of documents and other efforts designed to improve the energy efficiency of industrial facilities. Initially, assessment standards and guidance documents 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 Assessment Standards, which set the requirements for conducting and reporting the results of a compressed air, process heating, pumping, and steam assessments

(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 apply the assessment standard properly

(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: ANSI/MSE 2000:2008 will eventually be superseded by ISO 50001, now under development.

(d) an ANSI measurement and verification protocol that includes methodologies for verifying the results of energy efficiency projects

(e) a program, Superior Energy Performance, that will offer an 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-wide or site-wide energy plans.

Publication of this Technical Report that has been registered with ANSI has been approved by ASME. This document is registered as a Technical Report according to the Procedures for the Registration of Technical Reports with ANSI. This document is not an American National Standard and the material contained herein is not normative in nature. Comments on the content of this document should be sent to the Managing Director, Technical, Codes and Standards, ASME.

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

The Committee welcomes proposals for revisions to this technical report. 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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GUIDANCE FOR ASME EA-1, ENERGY ASSESSMENT FOR PROCESS HEATING SYSTEMS

1 SCOPE AND INTRODUCTION

1.1 Scope

This guidance document provides an application guide on how to utilize ASME EA-1, Energy Assessment for Process Heating Systems. This guidance document provides background and supporting information to assist in applying the standard.

1.2 Limitations

ASME EA-1 does not provide guidance on how to perform a process heating energy assessment, but sets the requirements that need to be performed during the assessment. ASME EA-1 was written in a form suitable for a standard, with concise text and without examples or explanations. This document was developed to be used in conjunction with the standard in order to give basic guidance on how to fulfill the requirements of the standard. This document is only a guide, does not set any new requirements, and ASME EA-1 can used with or without this document.

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: furnace into which the entire workload is introduced periodically.

continuous furnace: furnace into which the workload is introduced continuously or at short time intervals.

energy intensity: the ratio of the energy used during a heating operation to the product unit or mass that absorbs the energy. Also called "specific 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 base line units are Btu/lb (kWh/kg), Btu/hr (kW), or Btu/unit of product (widget) (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: term generically 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 such terms as Btu/hr, kW, kCal/hr, and 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 such terms as lbs/hr, t/hr, or number of pieces/hr 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 such heating equipment as furnaces, melters, ovens, and heaters.

resource utilization: use of such available resources 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 OVERVIEW OF THE STANDARD — HOW TO USE ASME EA-1

ASME EA-1 is organized as described in paras. 3.1 through 3.7.

3.1 Section 1: Scope and Introduction

This section includes the scope for the standard, limitations of the standard, and an introduction on how to use the standard that includes information on the systems approach and the system engineering process. No guidance is provided for this section of the standard.

3.2 Section 2: Definitions

This section includes definitions of terms used in the standard. No guidance is provided for this section, and these definitions are repeated in section 2 of this document.

3.3 Section 3: References

This section includes documents that are referenced in the standard. No guidance is provided for this section of the standard.

3.4 Section 4: Organizing the Assessment

This section includes requirements on how to organize an assessment including identification of team members and responsibilities, requirements for preliminary data collection and analysis, and requirements on the development of assessment goals and a plan of action. Guidance is provided in section 4 of this document.

3.5 Section 5: Conducting the Assessment

This section includes requirements on how to conduct an assessment (the implementation phase of the plan of action). Guidance is provided in section 5 of this document.

3.6 Section 6: Analysis of Data From the Assessment

This section includes requirements on how the analyze the data collected during an assessment, including the development of a baseline profile. Guidance is provided in section 6 of this document.

3.7 Section 7: Reporting and Documentation

This section includes requirements on how to structure the assessment report. Guidance is provided in section 7 of this document.

4 GUIDE TO ORGANIZING THE ASSESSMENT

An assessment work plan should be prepared and reviewed with the team members. An example of a typical work plan is given in Nonmandatory Appendix C.

4.1 Identification of Assessment Team Members

There is no additional guidance for this clause.

4.1.1 Required Functions and Personnel. Potential assessment team members to fill the functional roles identified in ASME EA-1 could include those listed in (a) through (d).

(a) Authorized Manager. An authorized manager should accept overall responsibility and have final decision-making authority. Responsibilities could include supervising the assessment team and providing resources necessary to plan and execute the assessment. Resources include such items as funding, availability of company personnel at the plant site, and, as necessary, requisitioning internal work orders and supplies. The manager should also allocate and authorize the participation of outside contractors and consultants, and, as necessary, oversee the participation of outside personnel including contracts, scheduling, confidentiality agreements, and statement of work.

(b) Assessment Team Leader. Plant management can demonstrate commitment to the assessment goals, objectives, and activities by appointing a system assessment team leader familiar with the processes, systems, and equipment related to process heating in the plant. The team leader should be familiar with operating and maintenance practices for the process heating equipment (or should have access, during the assessment, to people who are) and should be empowered to obtain necessary support from plant personnel and other individuals and organizations during the assessment.

(c) Process Heating Expert. The team should include a process heating expert. This individual, either a corporate or plant employee or outside consultant, should have the requisite qualifications, background, experi-

ence, and recognized abilities to perform the process heating assessment activities, data analysis, and report preparation.

(d) Roles and Responsibilities of the Team Leader. Responsibilities of the team leader can include

(1) forming the assessment team and identifying process heating experts, other team members using criteria given in paras. 4.1.2 and 4.1.3, and obtaining the other resources required for the system assessment.

(2) identifying process heating systems and equipment used in the plant, and managing the collecting, analyzing, and reporting of energy use data on individual systems and totals for all systems, if available. This should be done in cooperation with the team.

(3) coordinating and facilitating assessment activities with plant personnel, team members, experts, and other resources, if used, during the assessment.

(4) leading the team in preparing an assessment report that meets the requirements identified in section 7 of ASME EA-1 and that has the team's endorsement and support.

(5) reporting the results of the assessment to plant management and agreeing on future actions.

(6) understanding plant and corporate goals.

4.2 Facility Management Support

Prior to the assessment, the authorized manager should provide written commitment to the team via the team leader and support to the assessment through

(a) appointing a team leader who satisfies the requirements defined in para. 4.1.2 of ASME EA-1

(b) communicating to the team leader the corporation's overall plan for the assessment, including timing, scope of the study and extent of the resources committed to it, in-house manpower, funds, equipment, and identification of any outside experts or consultants retained to assist with the assessment

(c) committing the necessary resources to the process

(d) communicating to the organization the importance of the assessment and the need to cooperate with the assessment team

(e) providing information and other resources necessary for the assessment activities

(f) attending the required meetings

(g) where corporate resources permit, following through on the recommendations made in the assessment report

4.3 Communications

There is no additional guidance for this clause.

4.4 Access to Equipment, Resources, and Information

There is no additional guidance for this clause.

4.5 Assessment Goals and Scope

There is no additional guidance for this clause.

4.6 Initial Data Collection and Evaluation

The following data should be obtained. Possible sources of the required data are given. This information can be used to prioritize the equipment that would be considered for a detailed energy assessment using the methodology described in ASME EA-1.

(a) Power Input Ratings

(1) Units. Power input ratings (when available) are given in terms of units such as kW, Btu/hr, or other similar units.

(2) Data Sources. Data sources include plant process or production and operating personnel, equipment name plates, operating or instruction manuals, equipment drawings, vendor catalogs or other materials supplied by the vendor, or contacts with the vendor/supplier. Be alert to the possibility the equipment has been changed and existing documentation may no longer be accurate. Confirm the units, because energy input ratings can be expressed in a variety of units such as Btu/hr, kW, mJ/h, therms/hr, ft^3 or $N{\cdot}m^3$ of gas per hour, gallons of fuel oil per minute, etc. In some cases it may be necessary to get information on heating value of the fuel used. The stated value should be converted to an agreed upon preferred unit with the converted original unit placed in parentheses after the preferred figure, such as kW (mJ/h). This preferred unit should be one that is widely used in the plant.

(b) Production Rate

(1) Units. Production rate is given in terms such as lb/hr or units/day. Both the vendor rating and the actual production rates should be collected and compared.

(2) Data Sources. Data sources include plant process or production and operating personnel, name plates, operating or instruction manuals, equipment drawings, vendor catalogs or other materials supplied by the vendor or contacts with the vendor/supplier, and normal operating temperature or range of operating temperatures with appropriate units. These should be expressed in conventional units such as degrees Fahrenheit (°F), degrees Celsius (°C), kelvin (K), or degrees Rankine (°R).

(c) Normal Operating Temperatures

(1) Specific Operating Conditions. Normal operating temperatures should be related to specific operating conditions; for example, "normal operating temperature of 1,000°F at a production capacity of *** lb/hr" or "for the production cycle ***," etc.

NOTE: *** indicates appropriate values.

In general, these temperatures should be actual product temperatures, but air temperatures are frequently measured and noted as such. For product temperatures,

FORM 1 EXAMPLE OF DATA COLLECTION

Name of Equipment		Furnace 1	Heater 1	Oven 1	Kiln 1	Thermal Oxidizer	Melter	Dryer
Operating temperature	Units							
	Value							
Power input rating	Units							
	Value							
Production rate	Units							
	Value							
Type of operation (check one)	Batch							
	Continuous							
Energy use	Units							
	Value							
Energy cost	Units							
	Value							
Type or name of energy used								
Other information								
1								
2								
3								

GENERAL NOTE: See para. 4.6 for additional information on description and data source.

record the location and method of this measurement, because it can vary within a load or bath.

(2) *Data Sources.* Data sources include equipment nameplates, operating or instruction manuals, equipment drawings, vendor catalogs or other materials supplied by the vendor, plant process or production and operating personnel, or contacts with the vendor/supplier.

(d) *Energy Use*

(1) *Units.* Energy use is given in terms such as Btu/hr, Btu/day, or Btu/yr.

(2) *Data Sources.* Data sources include actual meter data (integrated over a certain time period or instantaneous and then integrated over a period of time), estimates (see estimation notes below), or vendor-supplied material (user manuals, drawings, etc.).

(e) *Energy Cost per Unit of Energy*

(1) *Units.* Energy cost is expressed in units such as \$/MMBtu or \$/kWh, with clarification on issues such as whether this includes all charges (purchase, transmission, distribution), any peak charges or demand charges, etc. The final cost should be calculated to account for energy used and its total cost to the user.

(2) *Data Sources.* Company energy manager's office or accounting department or purchasing department for the plant or the company.

(f) *Other Items*

(1) Other items may include

(a) type of energy use with appropriate information such as heating value for the type of energy source expressed in appropriate units

(b) number of operating hours per year, source of energy, pressure-temperature of the energy source (if applicable), etc.

(2) *Data Sources.* Data sources include equipment name plates, operating or instruction manuals, equipment drawings, vendor catalogs or other materials supplied by the vendor, plant process or production and operating personnel, standard handbooks, or contacts with the vendor/supplier. The stated value should be converted to an agreed-upon preferred unit with the converted original unit placed in parentheses.

NOTES:

(1) 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.

(2) For continuous heating processes with little or no variations in loading, energy use can be estimated relatively easily, because the different heating zones of the device tend to settle in at certain inputs and remain there. Batch-type operations normally experience wide variations in heating rate over the cycle. One way to construct an estimate is to check the input at regularly spaced time intervals and average them over the entire cycle.

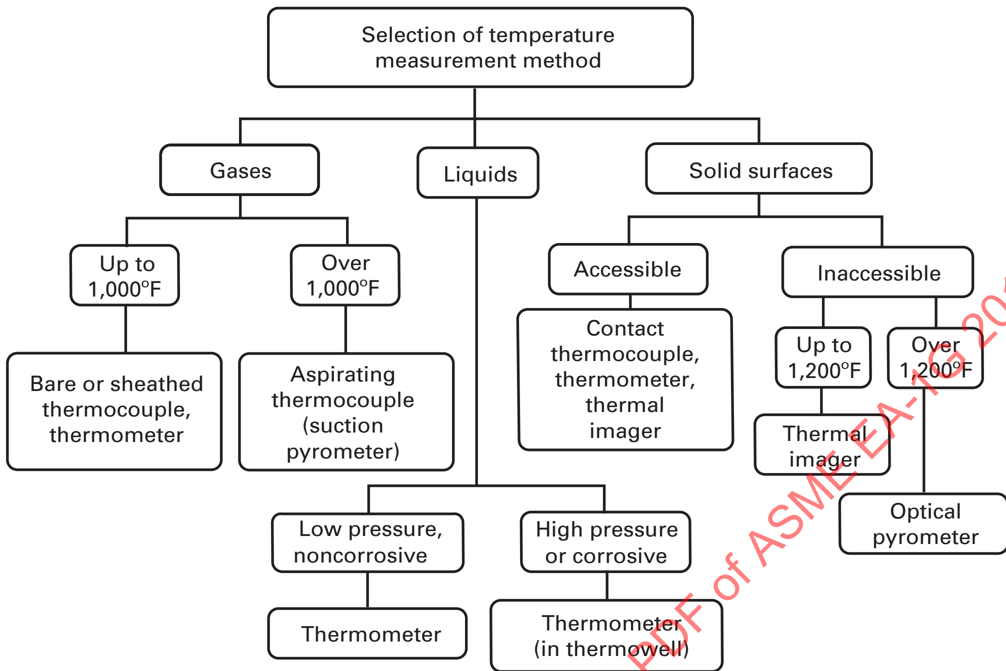
(3) Instantaneous heating rates can be estimated by taking flow readings from nonrecording meters over a period of time ("clocking the meter"), monitoring electrical current flows to heating elements, or in the case of burners, monitoring air and fuel pressures and pressure drops and using them to calculate flows from the manufacturers' data sheets.

4.6.1 Initial Facility Specialist Interviews. There is no additional guidance for this clause.

4.6.2 Energy Project History. The sample form presented in Form 1 can be used to collect preliminary data.

For batch processes additional data that may be collected include operating cycles, cycle time, number of hours or

Fig. 1 Guide on Selection of Temperature-Measuring Instruments



production shifts the equipment operates, idling time, and variations in load sizes and cycle temperatures.

4.6.3 Primary Energy Cost. There is no additional guidance for this clause.

4.7 Site-Specific Goals

There is no additional guidance for this clause.

4.7.1 Preliminary Selection of Process Heating Systems for Assessment. There is no additional guidance for this clause.

4.8 Assessment Plan of Action

There is no additional guidance for this clause.

4.8.1 Definition of Data Collection Requirements and Methods

4.8.1.1 Measuring, Metering, and Diagnostic Equipment Required

(a) Electrical Power Measurement for Electrically Heated Systems. For electrically heated systems energy use can be measured by using readings directly from a watt-hour meter (usually induction watt-hour meter) or by collecting data for the supply voltage, current, and number of phases for the power supply and power factor. For multiphase systems (such as commonly used three-phase systems), it is necessary to measure voltage and current for all three phases and calculate power by using the average value of the current with a power factor correction. Most plants have the required instruments. Power can be calculated by using the following equation:

$$\text{power (kW)} = [\text{voltage (volts)} \times \text{current (amps)} \times (\text{number of phases})^{0.5} \times \text{power factor}]/1{,}000$$

In cases where a power meter is installed on the equipment or a power measuring instrument is available, the instrument is almost always designed specifically to show power use for the equipment. As an alternate, a portable instrument may be used. It is composed of clamp-on or split CTs, amp and voltage meters, voltage leads, and the instrument itself. There are many manufacturers of this equipment. Each manufacturer has wiring diagrams to show how its instruments should be attached to the power feeder or branch circuit, and there are different configurations based on the type system, wye or delta, and balanced and unbalanced load.

Readings of this instrument can be obtained on an instantaneous basis or as integrated readings for a predefined time period. This information can be used to document total energy use for the heating system being assessed.

(b) Gas Temperature Measuring Instruments, Such as Thermocouples and Thermometers. Surface temperature measurement instruments include infrared pyrometers and contact thermocouples.

Figure 1 shows a general selection guide for temperature measurement in process heating systems.

For high-temperature (>1,500°F) flue gas temperature measurement, an aspirating thermocouple, also known as a suction pyrometer, will produce the most accurate results. Bare wire or metal-sheathed thermocouples provide a good combination of sensitivity and fast response,

Table 1 General Guide for Temperature Measurement Instruments Used in Industry

Type	Temperature Range, °F	Most Common Application	Contact Requirement
Fluid filled	−300 to 1,100	Liquids, gases	Yes
Bimetallic	−100 to 800	Liquids, gases	Yes
RTDs	−300 to 1,200	...	Yes
Thermocouples			
Type J	32 to 1,400	Liquids, gases, surfaces	Yes
Type K	−328 to 2,280	Liquids, gases, surfaces	Yes
Type E	−328 to 1,650	Liquids, gases, surfaces	Yes
Type T	−328 to 660	Liquids, gases, surfaces	Yes
Radiation			
High temperature	500 to 4,500	Surfaces	No
Low temperature	−40 to 400	Surfaces	No

GENERAL NOTE: RTDs are resistance temperature detectors.

but their readings will be increasingly affected by ambient radiation as the temperature of their environment increases. Radiation-induced errors should be negligible below 1,000°F. Radiation effects can also be minimized by using thermocouples with small diameter hot junctions.

Air and liquid temperatures up to 1,000°F can be measured with thermocouples or dial thermometers.

For air and gas temperatures, the most accurate results will be obtained by inserting the temperature probe directly into the moving stream, collecting readings at several insertion depths, and averaging them. If it is not possible to access the interior, an approximation can be obtained by measuring the outside temperature of the pipe or duct (metal or plastic temperature — not the insulation temperature). This temperature will be lower than the actual fluid temperature. The error will be least on well-insulated, small diameter pipes and ducts, and it will be greatest on large ducts with little or no insulation. On bare pipes, the accuracy can be improved somewhat by covering the tip of the temperature probe with a patch of ceramic fiber or mineral wool insulation.

Likewise, the most accurate liquid temperature measurements will result from inserting the probe directly into the moving stream or into a thermowell projecting into that stream. Pipe skin temperatures will be lower than the fluid, but the error will be minimized if the pipe is well-insulated or if a piece of insulation is placed over the probe tip.

Many liquids, like cooling water, are measured at two points to establish a differential. In these situations, the absolute temperature values are less critical than the accuracy of the differential temperature. For that reason, it is important that the amount of insulation (or lack of it) is the same at both measuring points.

Radiation-based instruments such as infrared pyrometers permit measurements to be taken more quickly and from safer distances, and their field of view provides an averaging effect. However, temperature measurement by using pyrometers requires settings or correction for emissivity of the object for which temperature measurement is made. It is also necessary to consider the angle at which the instrument is sited. This is especially true for lower emissivity (shiny) surfaces. Use of incorrect emissivity value for the surface could introduce measurement errors. In addition, dust and fumes in the air between the pyrometer and the target can affect reading accuracy. Thermocouples are not affected by target emissivity, but are relatively slow to reach equilibrium temperature and must be held firmly in contact with the target surface.

A general guide for selection of the method is given in Table 1.

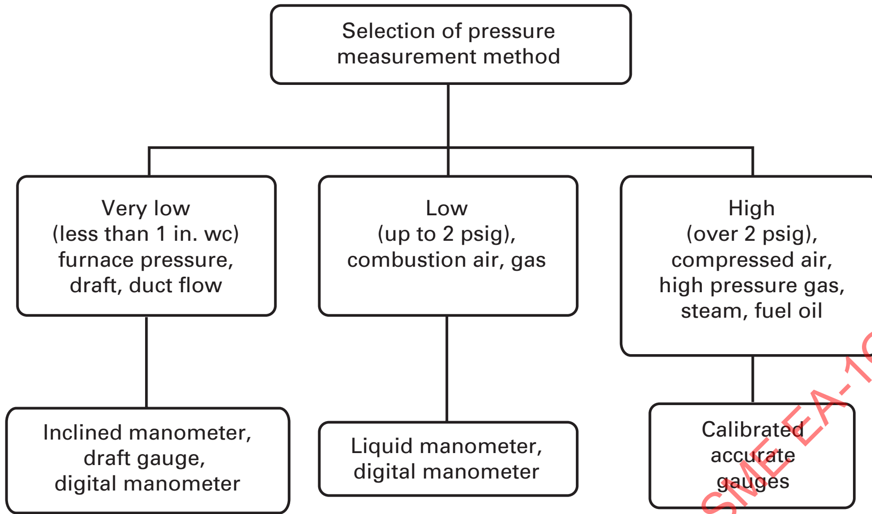
Other special-purpose instruments such as infrared cameras are used for measuring temperature of the load (charge, material, etc.) being heated and surfaces of process heating equipment.

Additional details and discussions on this subject can be found in standard handbooks. See references [7] and [8] for further details.

(c) Flue Gas Analyzer With Capability to Measure Oxygen (O_2) and Carbon Monoxide (CO). Capability to measure total hydrocarbons (HC) and carbon dioxide (CO_2) is desirable but not essential.

Flue gas analysis is often complicated by changes in burner firing rates during normal furnace or oven operation. Due to the time lag in getting the flue gases through the sampling train, the combustion control system may already be at a different firing rate and fuel-air ratio by the time the sample reaches the analyzer. The result is apparent random fluctuations in the flue gas composition. The simplest way to cope with this, if production considerations permit, is to manipulate the temperature control system to hold a fixed firing rate for enough time to obtain a stable flue gas sample.

Fig. 2 Guide on Selection of Pressure-Measuring Instruments



Additional information on flue gas measurement can be obtained from books such as reference [9] in Nonmandatory Appendix A.

(d) Pressure and Flow Measurements. For combustion air and fuel gas pressures, a measuring range up to 2 psig (55 in. water column or w.c.) is usually sufficient. Fuel oil and compressed air and steam pressures for atomizing may range up to 100 psig or higher. Internal pressures in ovens and furnaces are usually a few tenths of an inch w.c. positive or negative, requiring a resolution in hundredths of an inch w.c. Inexpensive pressure gauges are readily available but generally should be avoided unless they have been specifically calibrated for the assessment. Liquid-filled manometers have the highest inherent accuracy but may be cumbersome to use. Digital electronic manometers are more convenient to use and easier to read but should be calibrated against a reliable standard because of their tendency to drift over time. Figure 2 shows a general selection guide for pressure measurement in process heating systems.

For combustion air and fuel gas flows, orifice meters are commonly used. For smaller flows, such as fuel gases, a rotary meter can be used. If these instruments are not already present, considerable effort will be required to install them. This installation has to be done prior to assessment activities. As an alternative, the air and sometimes the gas flows to burners can be derived from static pressure measurements at or close to the burners. Most manufacturers provide pressure taps for this purpose, and flows can be determined from calibration charts or tables provided with the burners.

Flue gas flow measurements can be carried out with pitot-static tubes or similar flow-measuring devices, together with a manometer to measure differential pressures in the range of a few inches of water column. Liquid flows can be measured by rotary meters or clamp-on type flow meters and may require preparation for their use. Process gas flows (such as nitrogen) in small volumes (usually less than a few thousand cubic feet per hour) can be measured by using rotameters or flow scopes. Condensable fluid vapors such as steam can be measured by orifice meters, provided the vapors do not condense in the lines upstream and downstream near the orifice meter. In some cases, flows of liquids, vapors, and gases can also be measured with ultrasonic metering systems. Several new types of flow-measuring devices are being promoted, and they should be considered on a case-by-case basis.

Flow readings, particularly for gases (natural gas, air, etc.) should always be corrected to account for pressure and temperature of the fluid being measured. These corrections can be used to express flow rates at predefined standard conditions or at the desired operating (temperature and pressure) conditions.

Figure 3 shows a general selection guide for flow measurement methods in process heating systems.

4.8.2 Initial Measurement Plan: Where and When to Collect Data. Figures 4 and 5 show important areas and locations required for developing a typical heat balance. Note that these are only examples, and the team should consider additional areas or ignore the areas not applicable for a specific case.

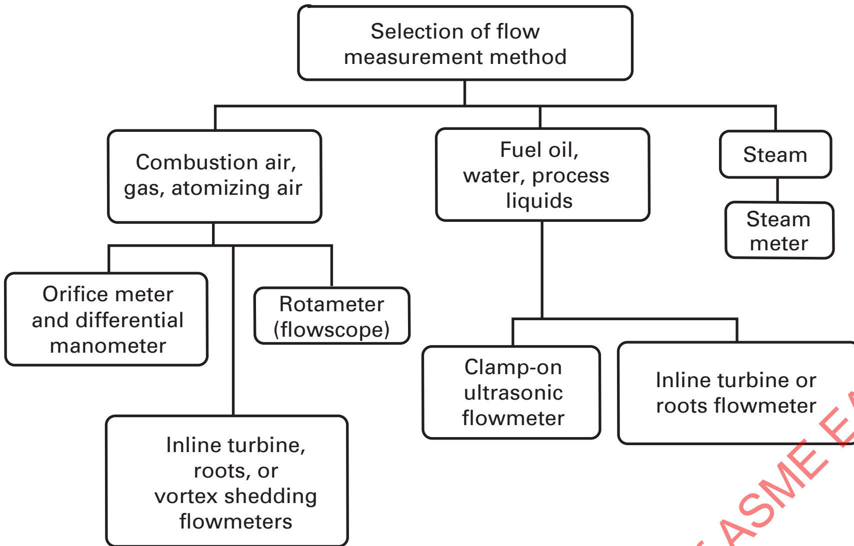
4.8.3 Identification of Other Assessment Team Members Required. The team leader should identify a number of team members to participate in the assessment activities. The team members should have knowledge of one or more aspects of process heating such as

(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

Fig. 3 Guide on Selection of Flow Measurement Methods



(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

Team members should be empowered to allocate the required time and resources as identified by the team leader.

4.8.4 Assessment Schedule. The team leader should prepare a schedule for the assessment activities. The schedule should 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 team leader should also make available, as needed, the following:

(a) a safety briefing.

(b) nondisclosure agreements.

(c) liability insurance requirements.

(d) requirements for personal protective equipment. The team leader should ensure all team members have the necessary equipment prior to the assessment.

(e) training or refreshers on any software used in the analysis.

4.9 Goal Check

There is no additional guidance for this clause.

5 GUIDE TO CONDUCTING THE ASSESSMENT

Figure 6 shows the assessment activities and their suggested sequence. This is included in ASME EA-1.

These activities and suggested actions are described as follows:

(a) Identify Equipment. Use the criteria discussed and suggested in para. 4.5.7.

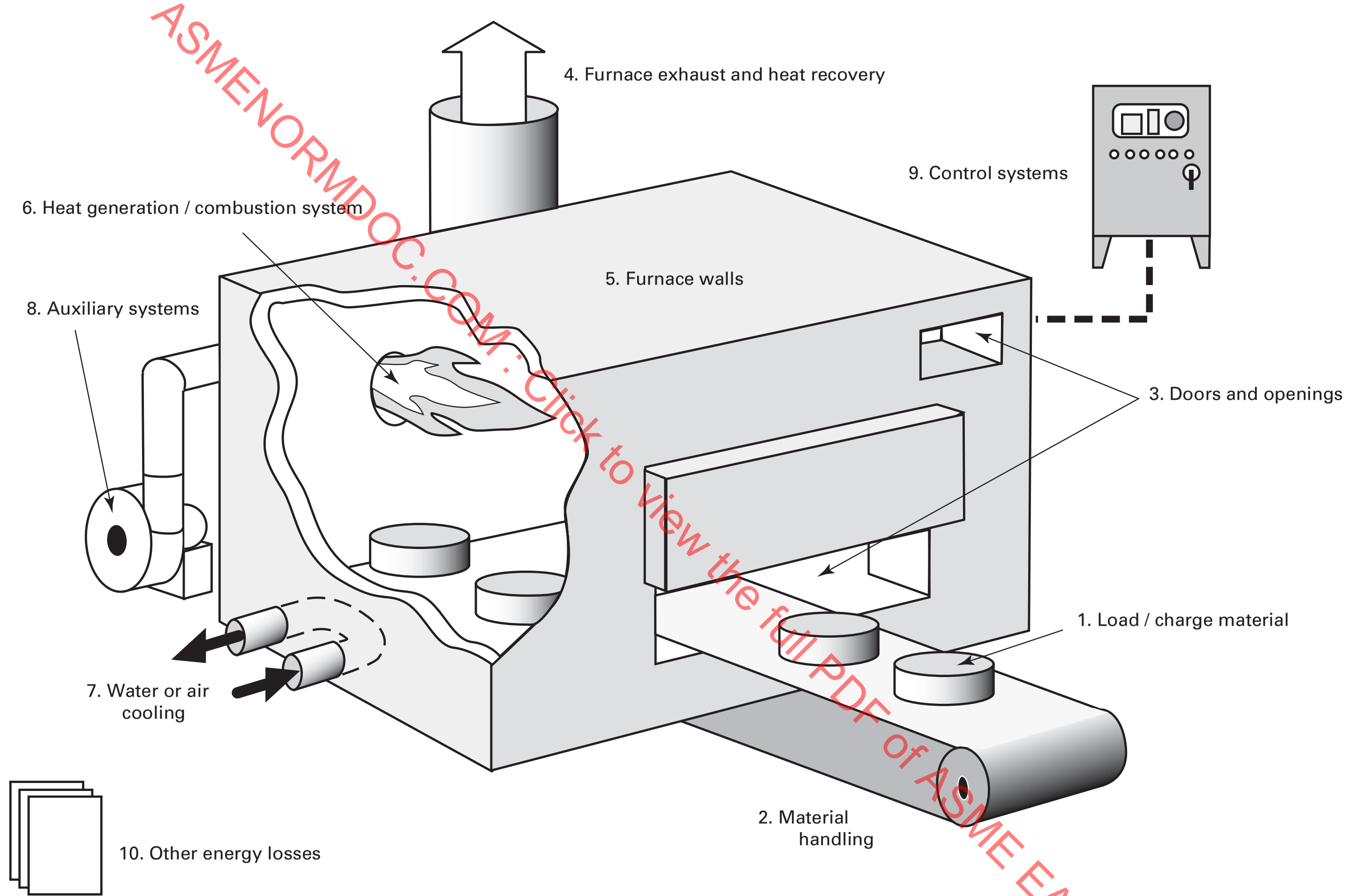
(b) Identify Operating Conditions During Assessment. Process heating equipment can be operated at different rates, where the key process parameters could be different from their design values. The operating conditions selected during the assessment must be as close as possible to the conditions at which the equipment is operated the majority of the time. Equipment operating history should be reviewed and used as a guide.

(c) Identify Data Requirements. Use information given in para. 4.6.3 to identify where and what type of data to collect for given equipment.

(d) Identify Data Sources. The required data can be derived from the following sources:

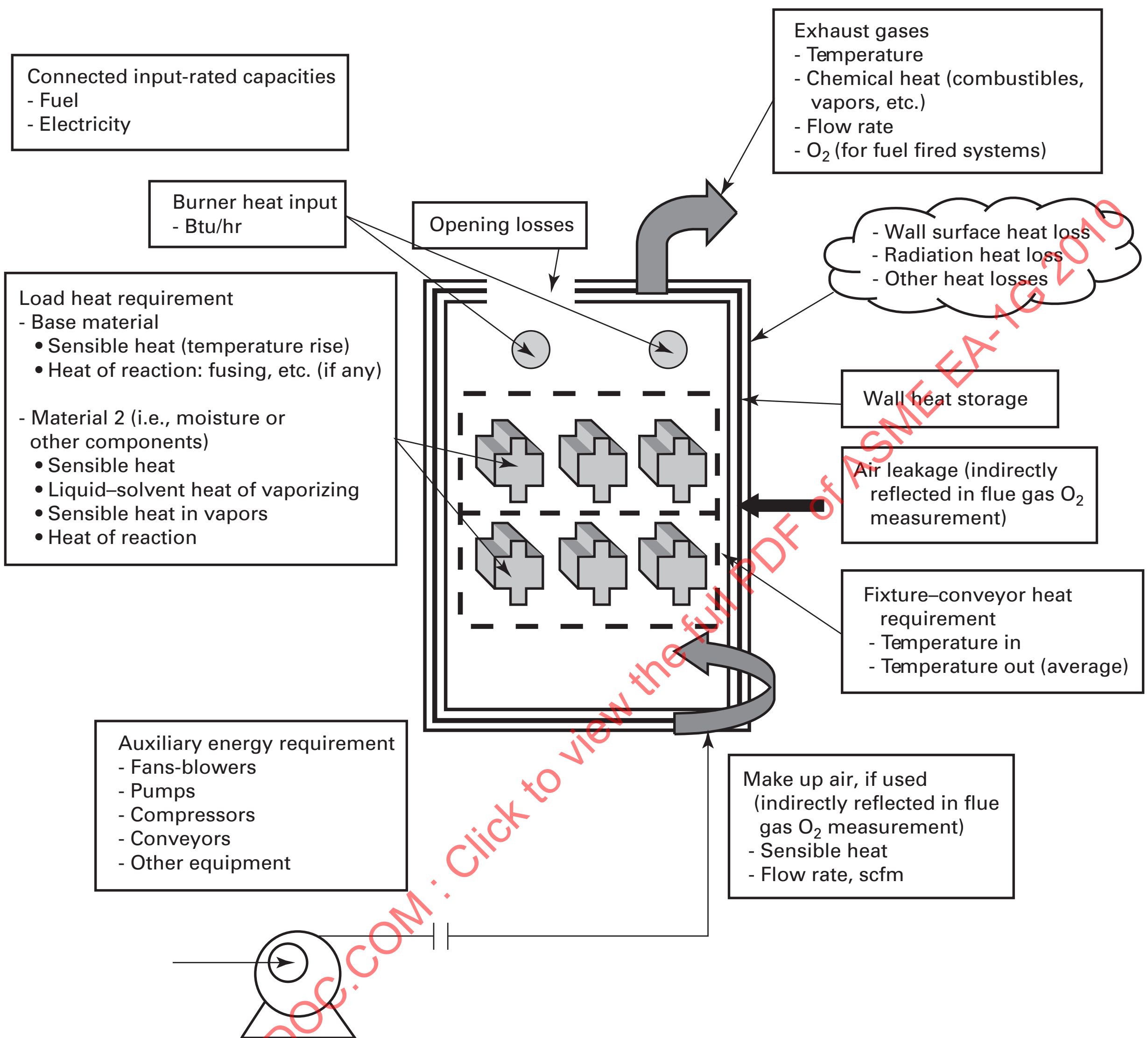
(1) data display on a computerized process or equipment control system. This data should be verified by spot-checking critical parameters from other data sources, such as control panels or permanent instruments installed on the heating equipment. For example, furnace temperature displayed on the computer screen should be verified by using a reading of a thermometer or thermocouple located inside the furnace near the thermocouple whose reading is displayed on the computer screen.

Fig. 4 Example of Important Areas to Be Considered for Data Collection During the Assessments of Process Heating Equipment



GENERAL NOTE: The numbers listed may indicate an ordering of the assessment.

Fig. 5 Example of Data That Needs to Be Collected During the Assessments of Process Heating Equipment



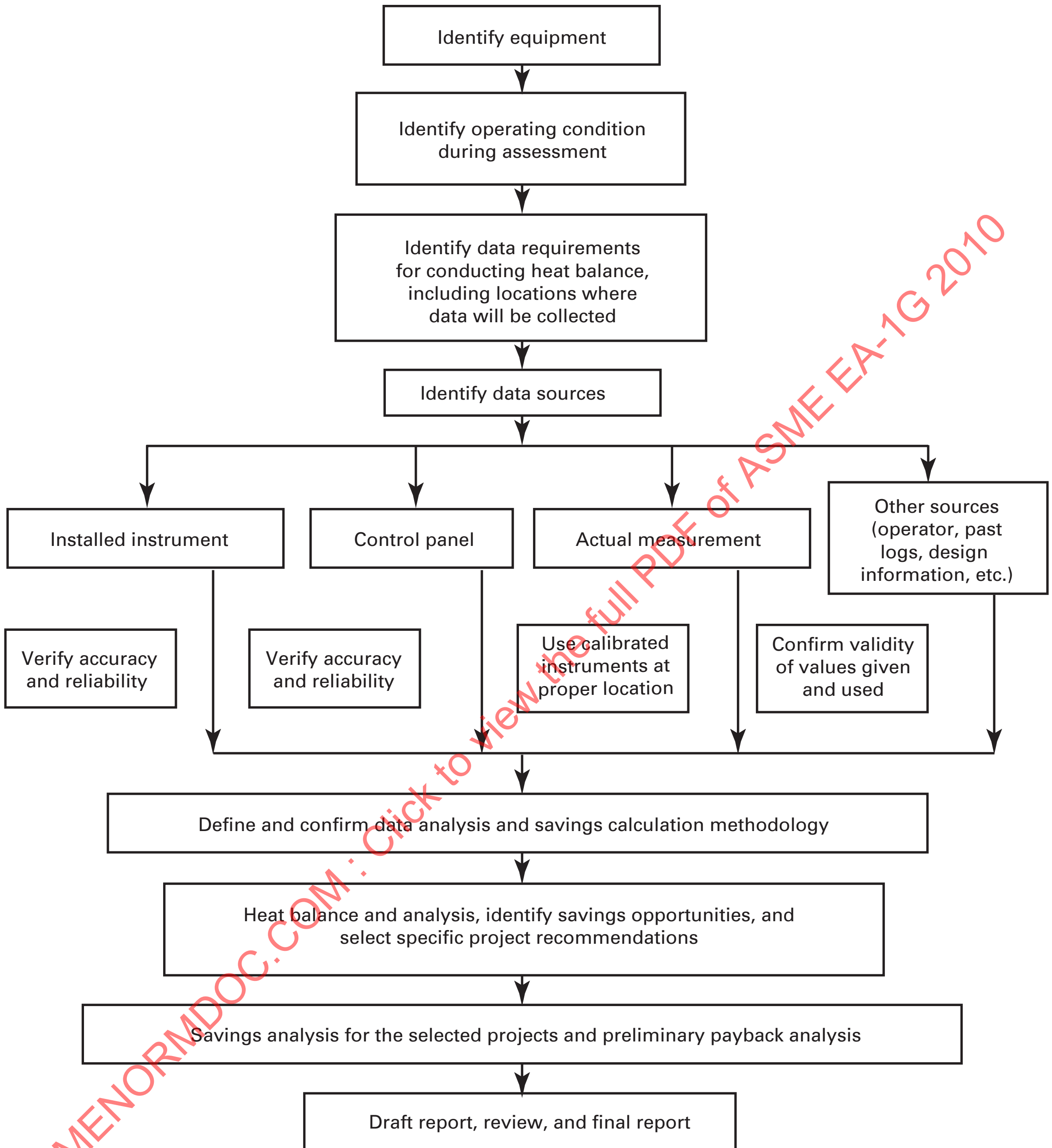
(2) control panels installed near the equipment. This data should be verified by spot-checking critical parameters from other data sources, such as a permanently installed instrument on the heating equipment. For example, furnace temperature displayed on the control panel should be verified with a thermometer or thermocouple located inside the furnace near the thermocouple whose reading is displayed on control panel.

(3) instruments installed on the equipment (e.g., pressure gage, temperature gage, differential pressure gage, or manometer). This data should be verified by spot-checking critical parameters from other data sources, such as a temporarily installed instrument on the heating equipment. For example, furnace pressure displayed on the instrument readout should be verified by using a probe and manometer that gives the actual value of the pressure inside the furnace as near as possible to the probe location of the installed instrument. Furnace pressure probes often have taps where a manometer or gauge can be installed, eliminating the need for a separate sampling probe.

(4) instruments installed or connected to the equipment, or probes especially for use during the assessment. Examples are flue gas analyzers, temperature or pressure probes, flow meters, etc. In this case, make sure that the instrument has been properly calibrated and its reading is trustworthy.

(5) vendor-supplied information (drawings, manuals, etc.). Where existing instrumentation or process controls are used as data sources, take the time to verify their accuracy. The same applies to manufacturers'

Fig. 6 List of Assessment Activities and Sequence as Required by the Process Heating Assessment Standard



drawings, manuals, and data sheets. Process heating equipment is commonly altered over time, and the original documentation may no longer reflect the present construction of the equipment.

(e) Define and Confirm Data Analysis and Savings Calculation Methodology. Process heating uses energy or heat in a large variety of ways. Data collection, its analysis, and energy savings calculations are very much dependent on the equipment and process used. The group may consider use of several sources including recommendations from the equipment supplier, in-house process heating expert, energy assessment expert, or a generalized method such as PHAST for this step. The selected method should be acceptable to the team members, since results obtained by use of this method will be used to identify energy savings, cost savings, and ultimate acceptance or rejection of the suggested energy efficiency projects.

(f) For Heat Balance and Analysis, Identify Savings Opportunities and Specific Project Recommendations

(1) Heat balance and energy savings can be carried out in a large variety of ways. The group may consider use of several sources including recommendations from the equipment supplier, in-house process heating expert, energy assessment expert, or a generalized method such as PHAST for this step.

(2) Energy savings opportunities should be based on considerations such as practicality of application of the identified opportunity, its effects on other issues, etc. The assessment team members should agree on the final selections.

(g) Financial Analysis. The assessment team should evaluate each project's economics using plant-accepted financial procedures.

(h) Draft Report, Review, and Final Report. The draft and final reports should be prepared using the suggested format given in section 7. The draft report should be reviewed, and comments should be submitted to the responsible person. The assessment team should agree on the report content.

5.1 Establishing Data Collection Priorities

The team should consider a list of data such as that given in Fig. 5 for various areas of a process heating system. It is likely that some of the areas and data listed in this figure may not be applicable to the system or equipment being assessed and therefore should not be considered. The team should consider relative importance of the data. For example, collection of data for calculating heat storage should be of low priority, whereas flue gas area should be of high priority.

5.2 Determining the Functional Requirement of Each System

The team should determine the ultimate goal or functional requirement of the heating operation to help set data collection priorities and, in some cases, degree of accuracy required for a particular measurement. For example, the ultimate goal of a heater could be to prevent metal oxidation or prevent dangerous chemical reactions. In this case, it is very important to measure the heater atmosphere, its temperature, and limits of allowable variations. On the other hand, for a heating system used to dry scrap material, such parameters may be of lesser importance and may not require such precise measurement.

5.3 Review of Permanently Installed Meters

The team members should review installed measurement sensors and instruments to determine the method of measurement, as well as any need and preparation for additional instruments. Table 2 gives a suggested format for recording the required information.

5.4 Identification of Control System and Strategy Used

The team members should review the type of process control system, its main components, and pertinent information for each of the important components. This will help in selection of type of measurements and additional measurements or instruments required for the assessment. Table 3 gives a suggested format for recording the required information.

5.5 Identification of Operating and Maintenance Practices

Process cycle temperatures versus furnace zone location or elapsed time in the furnace can be helpful in identifying locations and times for collecting the most useful temperature data. This information can be presented or collected in many different formats. A time–temperature curve for the furnace and the expected load temperature distribution, such as shown in Fig. 7, is a typical example. It is not necessary, and in many cases not possible, to examine such details. However, the team should try to get as much of this information as possible, because it may provide useful insights into the behavior of the equipment.

Maintenance practices and data should include, but not be limited to, preventive maintenance practices of the critical components of the system, maintenance carried out during the last 6 mo or 12 mo, records of emergency maintenance, etc. The objective is to collect data that would help identify opportunities for energy savings. A table similar to Table 4 should be considered.

5.6 Implementation of Measurement Plan (Data Collection)

5.6.1 Identification of Data Collection Requirements. A worksheet that shows the required data, the most suit-

Table 2 Suggested Table for Compiling and Recording Information on the Installed Meters

Instrument	Location	Measured Parameter	Units of Measurement	Range (Min. to Max.)
Pressure gage	Air duct: pipe	Air pressure	inch w.c.	0 to 55
Thermocouple	Furnace zone 1	Zone temperature	°F	200 to 1,000
O_2 meter	Flue gas duct	O_2 in flue gases	Percent O_2	0 to 10

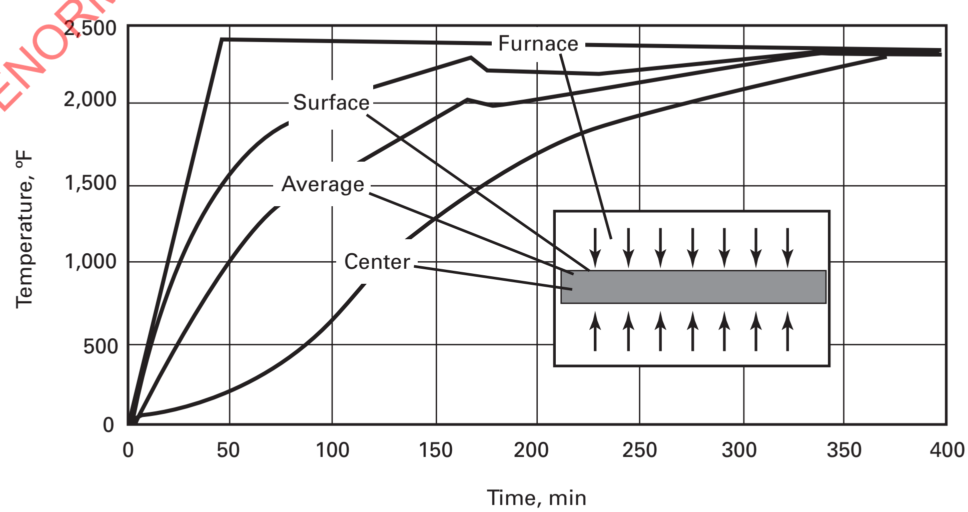
Table 3 Suggested Table for Compiling Information on the Control System

Controlled Parameter	Type of Control	Controlling Variable	Type of Control Mechanism	Range (Min. to Max.)
Zone temperature	Proportional controller	Burner air and gas flow	Valves in air line with use of a ratio regulator	100° to 1,000 °F
Oven pressure	Manual control	Stack damper	Mechanical linkage	−0.5 in. w.c. to +1.0 in. w.c.
Flue gas O_2	Manual control	Secondary air for combustion	Manually operated butterfly valve	0% to 10%

Table 4 Suggested Table for Compiling Information on the Maintenance Practices for the Heating System Used in the Plant

Equipment-System-Item	Maintenance Cycle	Activities	Last Maintenance Date	Comments
Furnace doors	Every 6 mo	Inspect gas, integrity and repair	June 2008	...
Flue gas analyzer	Every 3 mo	Check accuracy and calibrate	April 2009	Cell replaced in April 2009
Recuperator	Every year during annual shut down	Check air leaks, soot or other deposits on gas side, etc.	July 2008	Replaced expansion joints and repaired welds to eliminate air leaks
Fuel–air ratio	Every 3 mo	Check flue gas at high and low fire. Adjust gas flow controls as needed.	April 2009	High fire oxygen reading lowered from 4.5% to 2%, low fire O_2 left at 8%

Fig. 7 Example of Representation of Heating Cycle for a Continuous Furnace



FORM 2 SUGGESTED LIST OF INFORMATION: WORKSHEET FOR DATA COLLECTION PLANNING AND RECORDS

Name of the equipment: ____

Operating conditions: ____

Date: ________________ Time of data collection: ________________________

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

able source for that data, and method of validation is required. This matrix should be used to define the data collection activities. An example of a typical worksheet is shown as Form 2.

5.6.2 Determination of Data Collection Methods. Once the required data has been identified, the team should determine how it is collected. This should require the following:

(a) determination of the appropriate instruments to gather the data and ensure they are properly calibrated. A suggested format is shown in Table 5 and can be used as an example and guide.

(b) determination of the appropriate locations and installation procedures for data collection and the correct sampling equipment and procedures. A suggested format is shown in Table 6 and can be used as an example and guide.

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

The data should be collected at appropriate times during the production cycle. The timing should match the predefined production rate or other indicator for the desired assessment conditions. It may be necessary to collect data continuously or at several times during a heating cycle for batch processes.

5.6.3 Data Collection. The team may prepare its own sheets to be used for data collection. An example of data sheets used for PHAST analysis is given in Forms 3 and 4.

Form 3 shows a sample data sheet for collecting information on type of energy used, power or heat input ratings, equipment operating hours, etc. that can be used to estimate annual energy use and energy cost for the selected plant heating equipment.

Form 4 shows a sample data sheet for collecting operating data that can be used to develop a heat balance for the selected plant process heating equipment.

5.6.4 Data Review. There is no additional guidance for this clause.

5.6.5 Process Heating System Baseline. There is no additional guidance for this clause.

5.7 Wrap-Up Meeting and Presentation

The wrap-up meeting is intended to summarize the results to the team members, plant management, and others, to review available information and results obtained, and to give them information on the next required steps and the schedule for completion of the assessment activities. The meeting should be scheduled after completion of the data collection and preliminary data analysis that identifies possible areas of energy savings. If possible, a tentative list of recommended projects should be presented. The meeting should also be used to get comments and feedback from the attendees about implications and impacts on factors such as plant production, processes, and operating costs. Information obtained during this meeting should be used by the team in revising the recommendations and results. If necessary, key personnel who can contribute to further analysis should be identified, and plant management should ensure their availability during this phase of the assessment.

The following is an example of the structure and handling of a wrap-up meeting.

A wrap-up meeting should be attended by all team members and plant and company personnel who can contribute and guide the team in preparation of their recommendations.

A typical meeting may have the following agenda items:

Table 5 Suggested Format for Listing the Required Data and Details for the Data Acquisition

Required Data	Instrument to Be Used	Range: Scale	Calibration Verification	Remarks
Flue gas temperature	Suction pyrometer	100°F to 2,000°F	Calibrated on June 2, 2008	This requires at least a 6 ft long probe
Flue gas O_2	Flue gas analyzer model no.	0% to 21%	Cell changed and calibrated on June 2, 2007	The gas sampling probe should be made of Inconel and at least 6 ft long
Wall temperature	Infrared instrument or thermal imaging	0°F to 1,000°F	Factory calibrated: new	Use spot measurement if infrared is used; otherwise select at least a 20-ft^2 area for imaging

Table 6 Suggested Format for Listing Data Collection Equipment Instrumentation, Installation, and Sampling Procedure With Remarks

Required Data	Location	Installation Procedure	Sampling Procedure	Remarks
Flue gas temperature	Flue gas duct between the furnace outlet and the recuperator inlet	Install or insert a thermocouple probe in a port drilled in the duct wall	Sample temperature at high, intermediate, and low burner firing rates	Make sure that the port is properly sealed to avoid gas or air leakage through the port
Flue gas O_2 in furnace exhaust gases	Flue gas duct between the furnace outlet and the recuperator inlet	Install or insert a gas sampling probe drilled in the duct wall. Use a proper sampling system that includes a filter and gas drying device to get dry O_2 reading	Sample O_2 and CO at high, intermediate, and low burner firing rates	Avoid air leakage in the sampling line and properly seal the sampling port. Periodically drain the water trap to ensure a dry sample.
Wall temperature	Several areas of the furnace walls	None required if thermal radiation device is used	Collect readings at several locations and derive average value for heat losses for the wall. Use weighted average based on areas of each wall, the roof, etc.	Use proper value for the wall surface emissivity

(a) introduction of the team members

(b) assessment objectives and very brief summary of accomplishments

(c) summary of assessment activities, including information on the equipment that was assessed

(d) information on assessment process and issues encountered during the assessment

(e) preliminary results as available at the time of the meeting

(f) preliminary list of possible methods — steps for energy savings for the equipment assessed

(g) preliminary list of recommendations

(h) feedback and discussions

(i) next steps and schedule

6 GUIDE TO ANALYSIS OF DATA FROM THE ASSESSMENT

6.1 Introduction

There is no additional guidance for this section.

6.2 System Data Analysis

The assessment data analysis requires "translation" of the raw data collected during the assessment into useful information such as energy input, useful energy going into the product, and heat lost in several areas (wall losses, opening losses, flue gases, cooling, etc.).

The analysis method depends on the type of equipment, process, and degree of detail required. Several references (references [1], [2], [3], [4], and [6] given in Nonmandatory Appendix A) can provide the necessary equations, graphs, and information.

The team may develop calculation methods using standard formulas, equations, and graphs derived from the above-mentioned or other references. However, the source of information must be stated for each case.

An example of use of a spreadsheet to calculate heat losses in cooling water is given in Table 7.

An alternate approach for the analysis is to use the heat balance section of PHAST.

FORM 3 SAMPLE DATA SHEET FOR COLLECTING INFORMATION ON EACH TYPE OF HEATING EQUIPMENT TO BE ASSESSED

Survey Date: ____________________

Plant — General Information					
Company name					
Plant name					
Plant description					
Final product					
Contact name					
Phone		**E-mail**			
Currency in which costs are given					
Furnace Information (Use One for Each Furnace)					
Furnace name					
Furnace description					
Fuel (Energy Source) Information					
	Energy 1	**Energy 2**	**Energy 3**	**Energy 4**	**Energy 5**
Name of fuel/energy source					
Type (fuel/electricity/steam)					
Heating value units					
Heating value					
Cost unit					
Cost per unit					
Operating Hours Information					
	Weeks/yr	Days/Week	Shifts/Day	hr/Shift	Total hr/yr
Furnace Heat Zone Information					
	Zone 1	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Zone name					
	Fuel Firing for the Process or Furnace				
Fuel (energy source name)					
Number of burners per section/zone					
Burner rating (million Btu/hr) for ALL burners in the zone					
Approximate loading (% of full load)					
Rated capacity used in %					
	Electric Heating for the Process or Furnace				
Electric heating (kW) rating for ALL sections					
Approximate loading (% of full load)					
Rated capacity used in %					
	Steam Heating for the Process or Furnace				
Steam pressure, psig					
Steam temperature, °F					
Steam flow, lb/hr					
Total heat for steam, Btu/lb					
Approximate loading, % of full load					
Rated capacity used in %					
Auxiliary Equipment Information (Associated With the Furnace)					
Equipment		Total Numbers	Total Connected HP (ALL Equipment)	% of Cycle Time	% Loading
Compressors					
Vacuum pumps					
Pumps					
Fans/blowers					
Other motors					

FORM 4 SAMPLE DATA SHEET FOR COLLECTING OPERATING DATA ON EACH TYPE OF HEATING EQUIPMENT TO BE ASSESSED

Survey Date: ____________________

Furnace — Heat Balance Analysis	
Plant Name	
Furnace	

Fill out appropriate information for each type of heat load or loss for current and modified operating condition of furnace.

	Current Condition	Modified Condition		Current Condition	Modified Condition
Furnace Load Charge			**Other Losses (From Extended or Other Surfaces of Furnace)**		
Type of material (solid/liquid/gas)			Approximate area, ft^2		
Name of material			Average temperature, °F		
Charge weight rate, lb/hr			Ambient temperature, °F		
Moisture content, % (for solid charge) Vapor in gas mixture, % (for gas charge)					
Initial temperature, °F			**Atmosphere Losses**		
Water discharge temperature, °F (for solid charge)			Type of gas		
Discharge temperature, °F			Initial temperature, °F		
Specific heat of vapor, Btu/(lb-°F)			Final temperature, °F		
Percent charge weight melted (for solid charge) Percent charge vaporized (for liquid charge)			Atmosphere flow, ft^3/hr		
Heat of reaction					
Percent of weight reacted					
Fixture, Trays, Baskets, Etc. Losses			**Wall Losses**		
Type of material			Total surface area, ft^2		
Fixture weight rate, lb/hr			Average surface temperature, °F		
Initial temperature, °F			Ambient temperature, °F		
Final temperature, °F					
Water-Cooling Losses			**Opening Losses (Fixed)**		
Water flow (GPM) total for all water cooled areas			Furnace wall thickness, in.		
Inlet temperature, °F			Length of opening, in.		
Outlet temperature, °F			Diameter or height of opening, in.		
Flue Gas Losses (for Fuel Fired Furnace Only)			Total opening area, ft^2		
Furnace flue gas temperature, °F			Inside temperature, °F		
Percent oxygen in flue gas			Outside or ambient temperature, °F		
Combustion air temperature, °F			Percent time remained open	100	100
User defined available heat, %					
System Heating Efficiency (for Electrically Heated Furnace Only)			**Opening Losses (Variable)**		
Furnace temperature, °F			Furnace wall thickness, in.		
Electric heating system efficiency, %			Length of opening, in.		
System Heating Efficiency (for Steam Heated Furnace Only)			Diameter or height of opening, in.		
Furnace temperature, °F			Total opening area, ft^2		
Steam heating system efficiency, %			Inside temperature, °F		
			Outside temperature, °F		
			Percent time remained open		
Heat Storage	Use survey form on next page to collect storage data				

Additional Information

Table 7 Example of Cooling Water Loss Calculations That Could Be Developed by the Team Members or Expert

Cooling Water Heat Loss Calculations				
Parameter	Symbol	Units	Value	Data Source of Calculation Method
Cooling water flow rate	Mw	GPM	300	Measurement
Water inlet temperature	Tw-in	°F	65.0	Measurement
Water outlet temperature	Tw-out	°F	78.0	Measurement
Correction factor or density factor, if applicable	Cp	Btu/(lb-°F)	1.00	From literature
Heat loss in cooling water	Hcw	Btu/hr	1,950,390	See below

GENERAL NOTE: Equations used are as follows:
1 GPM of water = 500.1 lb/hr water flow rate
Heat loss in cooling water (Hcw) = Cp × Mw × (Tw-out − Tw-in)

Results of the analysis may be presented in the form of a table, pie chart, or in pictorial form such as Sankey diagram.

An example of a table is given in Table 8, an example of a pie chart is given in Fig. 8, and an example of a Sankey diagram is given in Fig. 9.

Note that the Sankey diagram would include values of energy in terms of units such as Btu/hr or Btu/lb of material processed or Btu/cycle to show energy supply and use distribution.

6.3 Calculations and Identification of Specific Energy Savings Opportunities

Energy savings opportunities for the assessed equipment can be identified by the team members based on their prior experience or discussion within the group. A list of possible areas of energy savings for process heating equipment is given in Table 9. The list is general and includes a large number of possible energy saving actions or activities. Not all opportunities will be applicable in all cases.

The selected activities or areas can be grouped in categories listed in paras. 6.3.1 through 6.3.6. The group should discuss and make a final decision on which item would fall under what category.

Areas of heat losses and corresponding energy saving measures for electrically heated systems depend on the type of heating (i.e., induction, resistance, infrared, dielectric, etc.). Due to large variations in energy saving methods for electrically heated systems, it is not possible to give a complete list of all energy saving methods. Detailed descriptions of the energy savings opportunities for commonly used electric heating systems are given in reference [5].

6.3.1 Examples of Maintenance Improvements. Maintenance improvements are defined as those that can be accomplished within the plant's operating or maintenance budget. Examples are given in para. 6.3.1 of ASME EA-1.

Although they might not yield large energy savings compared to more extensive capital projects, all should be listed in the report. If capital constraints prevent more ambitious plans, maintenance improvements may be the only short-term opportunity to obtain energy savings.

Wherever possible, lead time and labor expenditure required to accomplish these improvements should be noted if a financial analysis is performed.

6.3.2 Examples of Operational Improvements. Operational improvement recommendations should not be made without input from plant departments responsible for production and product quality. If the proposed improvements pose little or no risk, their evaluation should be incorporated into this report section.

6.3.3 Examples of Equipment Upgrades and Replacement. Discussion of each proposed upgrade or replacement technology should be accompanied by a cost-benefit analysis factoring in, if possible, contingent benefits such as lowered emissions and increased productivity. These will typically be capital projects.

6.3.4 Examples of Revising Control Strategies. Revised control strategies may be short-term expenses or longer-term capital projects, depending on their scope. If short-term, they should be treated as maintenance improvements, making note of the lead time and labor expenditure required to accomplish them, if a financial analysis is performed. If long-term, they should be treated the same as any other equipment upgrade.

6.3.5 Examples of Process Improvements/Changeovers. The nature of these changes ensures they will be long-term projects requiring input from all affected disciplines. Supporting comments from spokespeople representing

Table 8 Presentation of Results in Tabular Format

Area of Heat Consumption	Btu/hr
Net load weight	48,600,000
Flue gas losses	34,557,489
Water losses	9,764,118
Wall losses	3,556,748
Opening losses	132,914
Other losses	26,004
Fixtures losses	0
Atmosphere losses	0
Total	96,637,273

Fig. 8 Presentation of Results in Pie-Chart Form

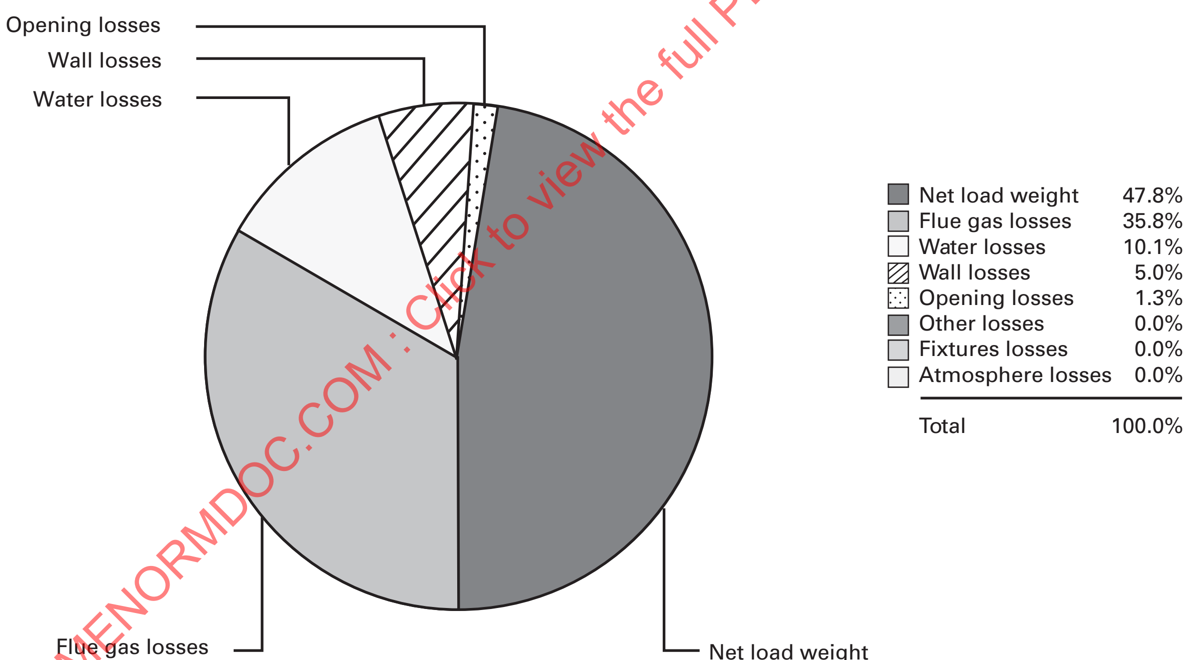
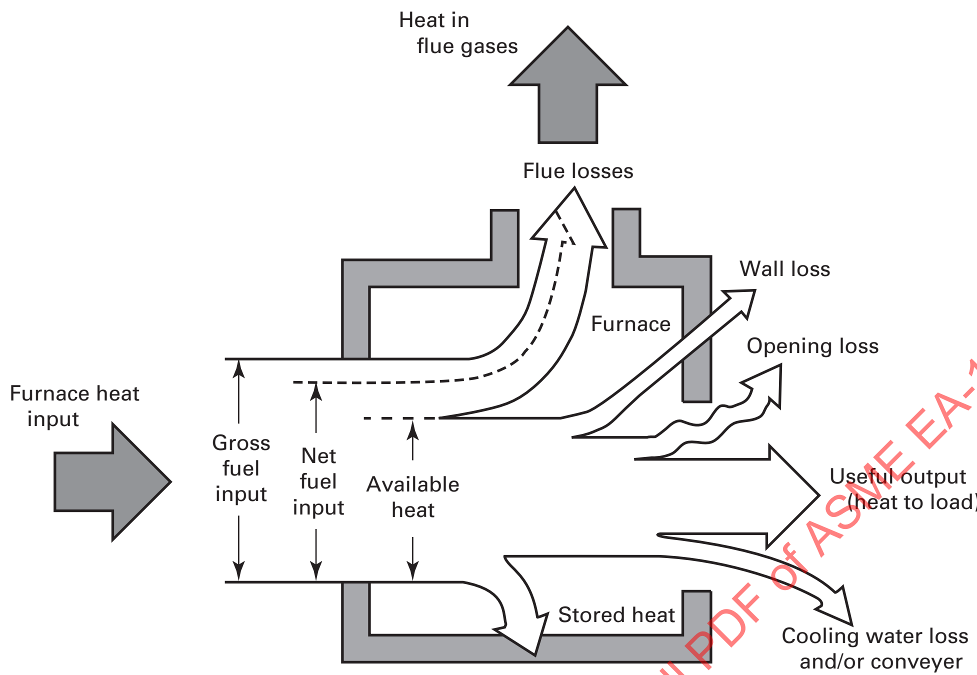


Fig. 9 Typical Heat Balance Representation Using the Sankey Diagram Format



those disciplines should be incorporated with these proposals to lend them credibility.

6.3.6 Examples of Other Energy Savings Opportunities. There is no additional guidance for this clause.

6.4 Energy Use Baseline

There is no additional guidance for this clause.

6.5 Technical and Financial Analysis

There is no additional guidance for this clause.

7 GUIDE TO REPORTING AND DOCUMENTATION

The report and documentation should follow the elements and content given in para. 7.2.

7.1 Final Assessment Report

There is no additional guidance for this clause.

7.2 Final Assessment Report Contents

7.2.1 Executive Summary. There is no additional guidance for this clause.

7.2.2 Facility Information. There is no additional guidance for this clause.

7.2.3 Assessment Goals and Scope. There is no additional guidance for this clause.

7.2.4 Description of the System(s) Studied and Significant System Issues. There is no additional guidance for this clause.

7.2.5 Assessment Data Collection and Measurements. There is no additional guidance for this clause.

7.2.6 Data Analysis. There is no additional guidance for this clause.

7.2.7 Energy Use Baseline. There is no additional guidance for this clause.

7.2.8 Performance Improvement Opportunities Identified and Prioritization. There is no additional guidance for this clause.

7.2.9 Recommendations for Implementation Activities. There is no additional guidance for this clause.

Table 9 Possible Areas of Energy Savings or Reduction of Heat Losses in a Process Heating Equipment

No.	Area of Heat Losses	Steps to Reduce Heat Losses
1	Heat in flue or exhaust gases from the heating system. This includes heat content of total mass of flue gases including air leakage into the system through openings; make-up air, moisture in flue gases or other source, etc.	Reduce excess air used for fuel combustion in burners. Control and minimize the amount of make-up air, if used, in ovens, dryers etc. Minimize air leakage by reducing size and number of openings and controlling pressure in the oven or furnaces. Recover heat by using heat recovery devices such as a recuperator for combustion air preheating, economizer for feed water heating, hot water production, steam generation, charge drying or preheating etc. Heat cascading – use high temperature exhaust gases to supply heat to lower temperature heating processes.
2	Heat losses from the heating equipment walls or outside surfaces.	Use proper type and thickness of insulation for furnace/oven walls. Repair and maintain insulation or refractories used for the walls and doors if used. Minimize door openings during charging and discharging the load or charge material.
3	Heat losses as heat content of material handling equipment such as conveyor, belts, trays, fixtures, etc.	Minimize the weight of fixture, trays, baskets, etc. used for material handling. Whenever possible return the conveyor belt, fixtures, etc. as hot as possible.
4	Heat stored in the refractories, insulation, or other materials used for the equipment itself when it is heated from lower temperature (usually ambient temperature) to the operating temperature.	Whenever possible avoid cooling of the walls of ovens and furnaces. Use them continuously. Keep the doors closed and adjust the stack damper to avoid "cold air draft" through the stack.
5	Heat lost in cooling system air or water, if used.	Avoid use of water cooled parts in furnace. If the cooling is necessary, insulate the water or air cooled parts if possible.
6	Heat losses through openings by thermal radiation.	Reduce openings, cracks, holes, etc. in the heating equipment walls. Minimize door openings during charging and discharging the load or charge material.
7	Heat content of special atmosphere or reaction gases introduced in the system or released from the material being heated when these gases or vapors are discharged at high temperature from the heating equipment.	Minimize the use of process atmosphere or reaction gases used in furnaces. Maintain seals and reduce atmosphere – gases leakage. Discharge the vapors or gases produced by drying or reactions at minimum possible temperature to reduce heat carried out by these gases.
8	Other losses	Operate the furnace or ovens at or close to the design capacity. Control and minimize use of auxiliary heating systems such as flame curtains or while following the safety guidelines. Minimize idling time for the furnaces and ovens. Conduct regular inspection and energy assessment for the large energy use equipment.

7.2.10 Appendices. There is no additional guidance for this clause.

7.3 Data for Third Party Review

All data collected during the assessment, calculation methods, results from the analysis, and any pertinent information must be saved and submitted as part of the documentation file to the assessment leader. The information can be in the form of electronic documents (Excel tables, Word files, Power Point presentations, etc.) This may be used for third party review in the future if necessary.

7.4 Review of Final Report by Assessment Team Members

The report should be submitted to the assessment team, who may distribute it to the team members and others for their review, with a specific deadline for submitting comments. The comments will be compiled by the assessment leader and submitted to the expert and/or individuals responsible for the final report.

The comments should be considered and, if necessary, the report content should be revised before the final report is submitted to the plant assessment leader.

NONMANDATORY APPENDIX A
KEY REFERENCES

A-1 PUBLICATIONS

[1] ASME EA-1, Energy Assessment for Process Heating Systems. Publisher: The American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, NY 10016; Order Department: 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007 (www.asme.org).

[2] Reed, Richard. 1986. *North American Combustion Handbook*, vols. I and II, North American Manufacturing Co., Cleveland, OH 44105.

[3] Baukal, Charles Jr. 2001. *The John Zink Combustion Handbook*, CRC Press, New York, NY.

[4] Industrial Heating Equipment Association. 1994. *Combustion Technology Manual*, Publisher: Industrial Heating Equipment Association, 5040 Old Taylor Mill Road, Taylor Mill, KY 41015 (www.ihea.org).

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

[6] The U.S. Department of Energy. 2005. *Improving Process Heating System Performance*, The U.S. Department of Energy, Washington D.C. *(http://www1.eere.energy.gov/industry/bestpractices/pdfs/process_heating_sourcebook2.pdf).*

[7] Guyer, Eric C. et al. 1989. *Handbook of Applied Thermal Design.* McGraw-Hill Book Co., New York, NY.

[8] The OMEGA® Temperature Handbook and Encyclopedia, vol. MMV™, 5th ed. Publisher: Omega Engineering, Inc., One Omega Drive, Stamford, CT 06907 (www.omega.com/literature).

[9] Flue Gas Analysis in Industry, 2004. Publisher: Testo, Inc., 40 White Lake Road Sparta, NJ 07871 (www.testo.com).

[10] Thumann, A. and Mehta, P., 2001. *Handbook of Energy Engineering*, The Fairmont Press, Inc., Lilburn, GA.

[11] Green, D. and Perry, R., *Perry's Chemical Engineer's Handbook*, 8th ed., 2008, McGraw-Hill Publications, New York, NY.

[12] Newman, D., et al., *Essentials of Engineering Economic Analysis*, 2002, Oxford University Press, New York, NY.

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 http://www.eere.energy.gov/industry under the "Software Tools" section:

(a) Process Heating Assessment and Survey Tool (PHAST)

(b) Combined Heat and Power Application Tool (CHP)

(c) NOx and Energy Assessment Tool (NxEAT)

(d) 3E Plus®

NONMANDATORY APPENDIX B
DIAGRAMS ILLUSTRATING SAMPLING INSTRUMENTATION LOCATION FOR CERTAIN MEASUREMENTS

Figures B-1 through B-5 illustrate correct and incorrect locations for measurement of certain critical data that is collected during the fired process heating equipment assessment. These figures should be used as a guide only.

Fig. B-1 Heating System With Combustion Air Preheating: Valid Measurements, Option 1

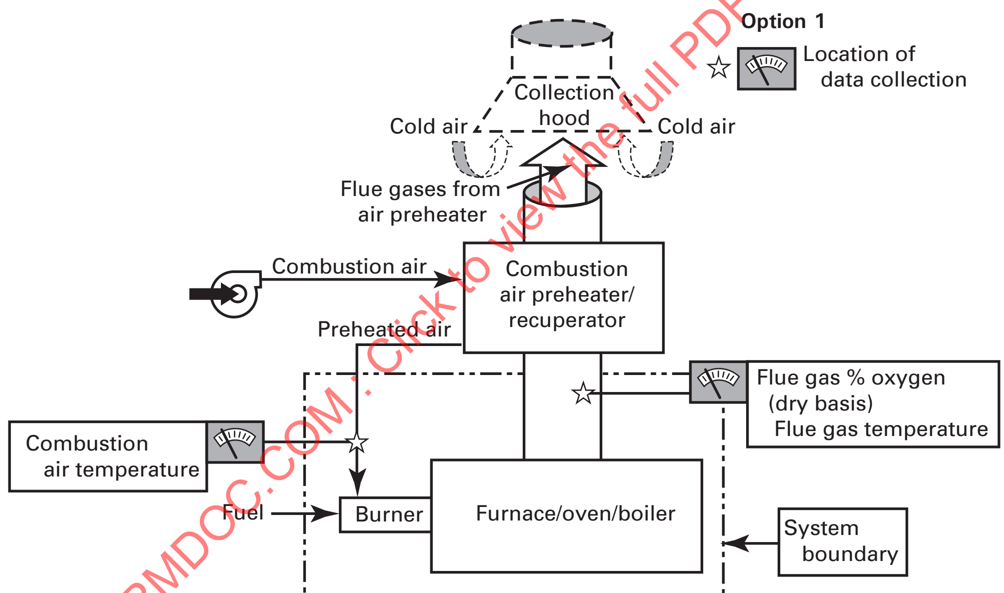


Fig. B-2 Heating System With Combustion Air Preheating: Valid Measurements, Option 2

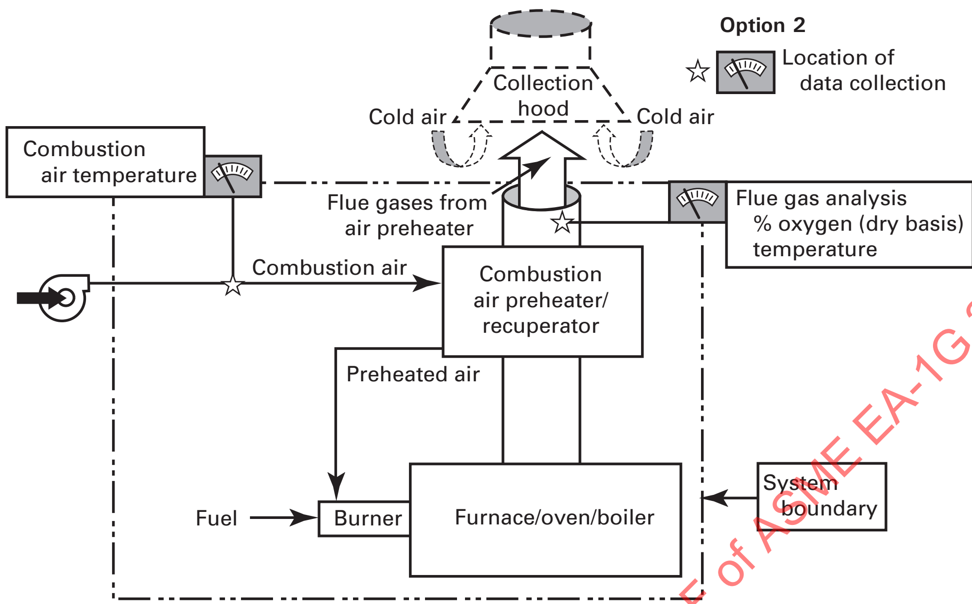


Fig. B-3 Heating System Without Combustion Air Preheating: Valid Measurements, Option 3