ASME EA-3–2009

Energy Assessment for Steam Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

ASME SETTING THE STANDARD

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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 steam systems, hereafter referenced as an "assessment." A steam system is defined as a system containing steam generator(s) or other steam source(s), a steam distribution network, and end-use equipment. Cogeneration and power generation components may also be elements of the system. If steam condensate is collected and returned, the condensate return subsystem is a part of the steam system. Assessments involve collecting and analyzing system design, operation, energy use, and performance data and identifying energy performance improvement opportunities for system optimization. An assessment 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 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 these types of services which 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 techniques, such as measurements, resulting in the identification, documentation, and prioritization of performance improvement opportunities.

This Standard sets the requirements for conducting and reporting the results of an assessment that evaluates the entire system, from energy inputs to the end use utilization of these inputs. An assessment that complies with this Standard need not address each individual system component or subsystem within an industrial facility with equal weight; however, it must 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.

The Standard is part of a portfolio of documents 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 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 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-wide or site-wide energy plans.

ASME EA-3–2009 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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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:

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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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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 STEAM SYSTEMS

1 SCOPE AND INTRODUCTION

1.1 Scope

This Standard covers steam systems that are defined as a system containing steam generator(s) or other steam source(s), a steam distribution network and end-use equipment. Cogeneration and power generation components may also be elements of the system (gas turbines, backpressure steam turbines, condensing steam turbines). If steam condensate is collected and returned, the condensate return subsystem is a part of the steam system.

This Standard sets the requirements for preparing for, conducting, and reporting the results of a steam system energy assessment (hereafter referenced 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 opportunities for improving the overall energy performance of the steam system. This Standard is designed to be applied primarily at industrial facilities, but most of the specified procedures can be used in other facilities such as those in the institutional and commercial sectors.

The scope of work shall be to complete a comprehensive assessment on a steam system. In the case of an exceptionally large facility, it may be desirable to focus on only one of several steam systems. As a result, the assessment plan should be developed for this specific system only. If an energy stream derives from or is directed to an adjacent system (possibly in an adjacent energy-supplying or receiving facility), then the details of the energy streams (e.g., electricity, steam, natural gas) shall be considered as part of the assessment of the target system.

Assessments involve collecting and analyzing data on system design, operation, energy use, and performance, and identifying energy performance improvement opportunities for system optimization. An assessment may also include recommendations for improving resource utilization, reducing per unit production cost, reducing life cycle 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; identifying energy performance improvement opportunities and making recommendations for system improvement and energy-saving project implementation 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 the plant or facility personnel's understanding of steam system energy use and operation.

This Standard sets requirements for:

(a) organizing and conducting a steam system 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 steam system assessment, but sets the requirements that need to be performed during the assessment. For additional assistance, see the companion *ASME Guide for ASME EA-3-2009 Energy Assessment for Steam* Systems on how to apply this Standard.

(a) This Standard does not specify how to design a steam 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 improvement opportunities in a steam system which consider all components and functions, from energy inputs to the work performed as the result of these inputs. Individual components or subsystems need not be addressed with equal weight, but 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.

assessment conditions: the operating conditions during the assessment period that serve as the basis of the measurements for the assessment investigations are identified as the *assessment conditions.*

baseline conditions: a set of operating conditions, and the associated system energy use, that the assessment team will use as a basis for calculating energy improvement opportunity impacts. Baseline conditions can, for example, be the assessment operating conditions, normal operating conditions, future operating conditions, or past operating conditions.

conservation of energy (energy balance): the application of the principle of *conservation of energy* as developed from the *first law of thermodynamics* is identified as an *energy balance.* Stated simply, the principle of conservation of energy is: *energy can neither be created nor destroyed by natural processes, it can only change form.* An energy balance can be applied to a single component, a composite subsystem, or an entire system.

conservation of mass (mass balance): the application of the principle of *conservation of mass* as developed from the *first law of thermodynamics.* Stated simply, the principle of conservation of mass is: *mass can neither be created nor destroyed by natural processes, it can only change form.* A mass balance can be applied to a single component, a composite subsystem, or an entire system.

efficiency: efficiency is a general term used to describe the effectiveness of energy utilization in a component, a subsystem, or an entire system. Specific definitions are ascribed to the various applications of efficiency. A general identification of efficiency that satisfies most applications is the ratio of the useful energy output divided by the energy input.

energy stream: a flow of material carrying energy across a boundary or within a system or subsystem in the forms of electricity, fossil fuel (e.g., natural gas, coal, process waste fuel), stack gas, steam, or water (including blowdown and condensate).

field measurement: the evaluation of a system variable through the use of instrumentation is a *field measurement.* Typical field measurements include temperature, pressure, and flow.

first law of thermodynamics: the *first law of thermodynamics* simply stated is *the combined amount of mass-and-energy is neither created nor destroyed by natural processes — it can only change form.* In other words, the amount of mass-and-energy in the universe remains constant. In steam system applications it is almost always appropriate to separate the first law of thermodynamics into the principle of the *conservation of mass* and the principle of the *conservation of energy.*

impact costs: the true economic influence of a commodity is identified as the *impact cost.* Impact costs are commonly expressed in terms of an applicable unit of energy ($\$/10^6$ Btu for example) and accurately reflect the financial influence of a specific system operational or equipment change. The manner of calculation of impact cost may vary, depending on a specific action considered.

model: one or more equations expressing conservation principles and other relationships that describes the characteristics of an energy system. The equation(s) may be solved manually (if sufficiently simple) or with computer simulation (computer model).

normal operating conditions: a set of operating conditions that are considered as periods of time when the equipment loading, system parameters, and process demands are reflective of typical or nominal conditions.

operating conditions: the operating conditions of a facility are the basic system characteristics, such as steam production, equipment loading, process demands, and many additional parameters. These conditions are both qualitative (e.g., type of boiler controls) and quantitative (e.g., boiler steam production level).

steam system: a system containing steam generator(s) or other steam source(s), a steam distribution network, and end-use equipment. Cogeneration and power generation components may also be elements of the system (e.g., gas turbines, backpressure steam turbines, condensing steam turbines). If steam condensate is collected and returned, the condensate return subsystem is a part of the steam system.

utility: a *utility* is identified as any energy commodity. This includes purchased electricity, onsite generated electricity, fuels, water, compressed air, and all other energy resource commodities supplied to the system. Steam is considered a utility as well.

3 REFERENCES

3.1 Reference Standards

There are no reference standards in this Standard.

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 steam 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 participate in the assessment process. Functions required to accomplish an assessment are listed in para. 4.1.1. The assessment team shall have members that are assigned responsibility and authority to carry out these functions. Information on other assessment team members is provided in para. 4.7.1.

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 Steam 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 the steam systems.

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

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, 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 steam system, it is necessary to physically inspect and make selected measurements on the system components. The assessment team shall have access to the following:

(a) all aspects of the steam system, including the generation, distribution, and end-use components. Plant areas that utilize steam and areas that contain the steam system are targets of the assessment.

(b) plant personnel (engineering, operations, maintenance, etc.), their equipment vendors, contractors, and others who have knowledge and 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 cost and supply information, computer monitoring and control data, electrical equipment panels, and calibration records. Pertinent plant production information to allow the assessment conditions, baseline conditions, and normal conditions to be identified should be included.

4.5 Initial Data Collection and Evaluation

The quality of an assessment is dependent on data gathering and data analysis. The assessment process can be optimized by assembling essential data at the beginning of the assessment process (and throughout the process). Critical preliminary information includes, but is not limited to, the following:

(a) general information on facility steam-generating and steam-using components, including schematic diagrams, and equipment listings

(b) utility rate schedules

(c) at least one recent year of historical steam system energy source consumption and cost data (boiler fuel,

electricity, and purchased steam bills), identification of multiple accounts, account representatives, salient energy use characteristics (e.g., seasonal variations, contract minimum purchase requirements, water, chemicals, and sewer costs)

(d) identification and prioritization of largest energy-using equipment, systems, and processes

(e) results of currently relevant steam system energy studies/surveys, if any (e.g., backpressure turbine study, steam trap study)

(f) identification of approved, initiated, rejected, and on-hold steam system projects

(g) identification of production and maintenance issues that affect or are affected by steam system performance

(h) boiler logs including general boiler operations, chemical analysis reports, steam production, condensate return, and others

(i) relevant steam system operational and maintenance records

(j) preliminary information of plant operating conditions as it pertains to the operation of the steam system

4.5.1 Initial Facility Specialist Interviews. The assessment team shall interview personnel and specialists within the plant to collect information on operating practices and other operating considerations that affect energy use for the equipment. This information shall be used to help develop the assessment goals and scope and the assessment plan of action (paras. 4.6 and 4.7).

4.5.2 Primary Energy Cost. Energy cost data shall be characterized in specific terms with units such as cost per energy unit ($/MMBtu or $/kWh), or other similar terms. The specific costs should consider all charges such as purchased cost, transportation cost, demand charges, peak rates, time-of-day rates, and any other costs up to the point of use. In many cases establishing the economic impact of an increase (or decrease) of an energy stream can require a complete system analysis. A facility may have already established a cost for energy — often these are based on blended or average conditions. Average values are appropriate in some cases; however, very often average costs do not reflect true economic impact.

4.6 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 evaluation of the performance of the key individual system components, evaluation of the performance of the entire system, and identification of performance improvement opportunities. The assessment will be conducted using a systems approach evaluating the true impacts of potential system changes.

The scope of the assessment shall define the portion(s) of the facility that is to be assessed. Many steam systems are sufficiently confined to allow the entire system to be assessed. However, some systems are extremely complex and widespread, requiring a segmented investigation approach. In these instances a clearly defined subset of the steam system can serve as the assessment scope as long as the boundaries are clearly defined and the interactions at the boundaries are appropriately evaluated.

As the assessment progresses, the potential improvement opportunities and the importance of individual components to these opportunities will become more clearly defined. As a result, the investigation strategy, measurement intensity, and critical parameters will be more clearly identified. These factors will enable more defined goals to be established. Therefore, the goals (and scope) of the assessment should be periodically reevaluated to ensure the focus of the assessment team is appropriately applied.

4.7 Assessment Plan of Action

To facilitate the assessment and clarify to all assessment team members how the assessment will be conducted, it is essential that an action plan for the assessment be developed and be agreed upon. The assessment activities and their sequence shall be defined. It should be noted that some actions/decisions depend on the findings during the assessment. The plan thus must be flexible and should accommodate various outcomes depending on such findings. In short, it is necessary to

(a) review initial data to identify how much is known about the systems

(b) identify assessment objectives

(1) Identify the systems that are going to be included in the assessment.

(2) Identify what additional data needs to be collected either through available records or by additional instruments.

(3) Identify the responsibility of collecting additional data.

(c) identify data analysis methods

(1) Identify how the data will be analyzed.

(2) Identify tools/software programs that are going to be used.

4.7.1 Identification of Other Assessment Team Members Required. Key plant personnel are of critical importance to the assessment. Typically, operations personnel, maintenance personnel, and area managers embody the bulk of the knowledge base in assessment target areas. It is essential to include these personnel in the assessment process.

If the facility has a designated projects improvement leader, this individual should participate in the assessment process. This will provide excellent opportunities for information exchange.

4.7.2 Assessment Scheduling. It is essential that the dates and times of the assessment, key meetings, and other assessment activities be scheduled well in advance of the beginning of the assessment. Examples of key assessment meetings include the following:

(a) safety orientation
(b) kickoff meeting
(c) key personnel interviews
(d) assessment progress meetings
(e) wrap-up meeting

4.8 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

5.1 Overall Assessment Method

The overall method to be used in assessing the steam system is a sequential screening process as shown in Fig. 1. This investigation process shall evaluate the operating characteristics of the individual components, the subsystem characteristics, and the overall system. In this manner, individual system components, subsystems, processes, and the system as a whole are to be examined in turn, with a finding of appropriate operating characteristics as currently operated, or with the identification of specific opportunities for improvement. When performance is found to be less than optimal, an investigation strategy to further evaluate the area will be established.

Evaluations of improvement opportunities will identify their true mass, energy, and economic impacts on the system as a whole. The characterization of the initial state of the assessed steam system and the quantification of identified opportunities for energy savings shall be based on adequate mass and energy balances as described in para. 5.1.1.

5.1.1 Mass and Energy Balancing. Evaluation of component operation and proposed modifications requires an investigation of the system interactions. The tools (principles) required to complete the investigations are the laws of physics. These laws are primarily employed in the forms of the principles of conservation of mass and conservation of energy (mass and energy balances). These physical relationships describe the operating characteristics of the components of the system. Often these evaluations are completed through the use of sophisticated computer program-based models of the system. However, less sophisticated calculation methods including manual calculation can be utilized if they are structured to appropriately account for system interactions. The general terms *steam model* and *system model* are applied to these calculation methods.

Mass and energy balances applied to a piece of equipment, a subsystem, or the entire system are statements of the principles of mass and energy conservation, which need to be understood in a steam system. Mass and energy balances shall be applied at any point in a steam system where flows of mass (e.g., water and steam) and energy (e.g., work and heat) enter and leave a system or component at flow distribution points. As examples, boiler efficiency, the use of steam in turbines, process equipment steam consumption, and steam consumption in boiler auxiliaries are all manipulations of mass and energy balances. A mass and/or energy balance should be needed for any or all of the following purposes:

(a) to calculate an unknown quantity (e.g., steam flow to a heat exchanger) from values of known or estimated quantities
(b) to verify that a set of measured and estimated values satisfies the operating conditions of the equipment
(c) to evaluate component efficiency and performance
(d) to determine the impacts of system modifications

In the case of unknown quantities in a mass or energy balance, it may be necessary to make reliable estimates of one or more needed values. Reliable estimates shall be based on the experience of the assessment team members reflected in typical values (e.g., turbine isentropic efficiency), plant experience in making similar measurements, design data (e.g., heat exchanger capacity) and available physical evidence (e.g., steam leak plume length).

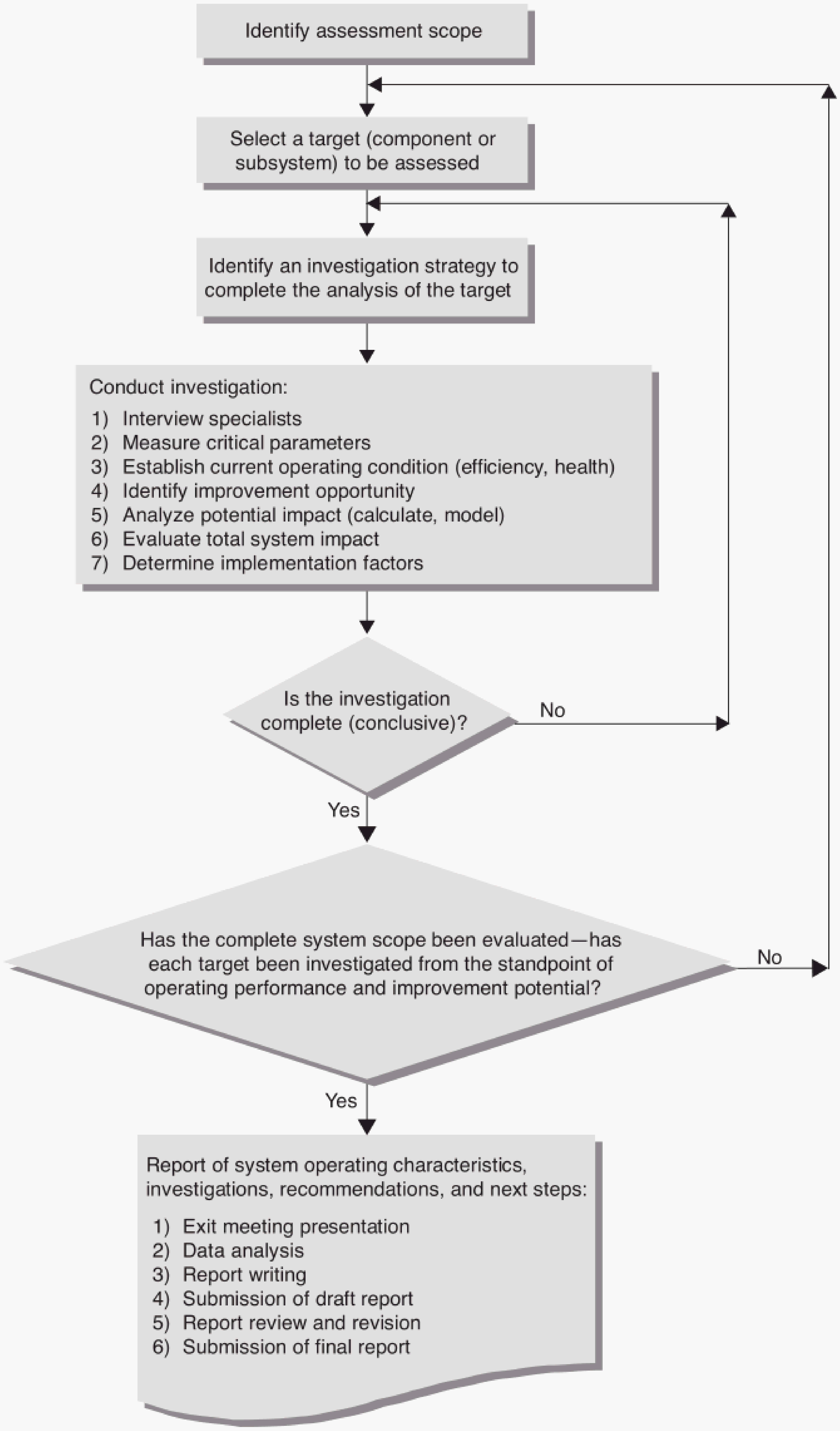
The accuracy or closure of the applied mass and energy balances should be in concert with the goal of the evaluation. For example, if an order-of-magnitude estimate is desired to establish general operating characteristics, then the tolerance of the mass and energy balances can be relaxed. However, if the end result of the analysis in question is to decide a specific project execution strategy, then the critical factors shall be accurately identified.

5.2 Kick-Off Meeting

The kick-off meeting will contain two parts:

(a) An introduction to management of the nature of the assessment, including
  (1) its focus and objectives
  (2) personnel involved
  (3) steps and procedures to be carried out
  (4) preliminary scheduling
  (5) the necessity for an exit meeting
(b) A working session to

Fig. 1 Assessment Method



(1) review available plant data and past assessment results

(2) establish normal steam system operating conditions

(3) discuss the tools, methods, measurement, metering, and diagnostic equipment required

In addition to the assessment team, the meeting should include plant or facility managers or their representatives, and other key plant personnel.

5.3 Facility Orientation Walk-Through

Following the initial meeting, an initial walk-through of the facility shall be conducted. The purpose of this guided inspection is for the assessment team to become aware of the existence and use of key steam system components and their relative locations in the facility. Locations of control rooms and where subsequent measurement(s) are to be made shall be noted. Energy-saving opportunities (e.g., steam leaks) shall be documented when initially discovered.

5.4 Target Areas for Assessment

An assessment includes evaluation of the steam sources (produced or purchased), distribution, end use, and condensate recovery. Assessment activities shall focus on quantification of energy losses and the identification and quantification of opportunities for reducing these losses.

Even though individual components are evaluated and investigated to determine their individual performance (paras. 5.4.1 and 5.4.2), the system as a whole shall be evaluated. Component and system interactions shall be accounted for in the system model.

5.4.1 The following equipment shall, as a minimum, be assessed:

(a) steam generation equipment

(1) conventional and by-product fueled boilers

(2) waste heat steam generators

(3) heat recovery steam generators coupled to combustion turbines

(b) combustion turbines

(c) steam turbine electrical power generators

(d) steam turbine equipment drives

(e) pressure-reducing valves and other system balancing components

(f) steam distribution systems (including thermal insulation and leaks)

(g) end-use equipment (e.g., heat exchangers, autoclaves)

(h) steam traps

(i) condensate return system components (e.g., flash vessels, return piping)

(j) heat recovery system components (e.g., heat exchangers, heated fluid storage tanks)

5.4.2 In addition to the steam system components to be assessed, opportunities for reducing energy use and/or energy cost by the following actions should be evaluated:

(a) fuel switching resulting in energy and/or cost savings

(b) replacing nonsteam process heating with new steam service or replacing steam service with an alternate energy source

(c) replacing electric motor drives with steam turbines or replacing turbines with electric motor drives

(d) recovering thermal energy from process units

5.5 Interviews of Specialists, Area Managers, and Operators

Interviews shall be scheduled for identified key specialists, area managers, and operators. Sufficient time should be allotted for a thorough discussion with each interviewed person having specific knowledge pertinent to the assessment. Knowledgeable individuals from all of the following areas (as a minimum) should be interviewed:

(a) facility energy manager

(b) purchasing agents familiar with boiler fuel purchases and the electrical rate structure

(c) boiler operations manager(s)

(d) process control room supervisors

(e) production (steam use) area supervisors

(f) maintenance personnel

(g) process engineers

(h) plant projects (improvements) leader

Steam system equipment targeted in the interview process should be inspected as well.

5.6 Conduct Detailed Evaluation With Measurements on Target Equipment/Components

Following the initial facility walk-through and discussions with all key specialists, the assessment team should revisit selected areas [e.g., boiler house, central condensate return station(s)] to study steam system operations in more detail, and to make needed measurements (e.g., temperatures, pressures, flow rates). For this phase of the assessment work, if reliable in-place measurement equipment is not in service, portable measurement equipment shall be used or permanent equipment installed. Situations needing a visual record should be recorded with sketches or photographs (as permitted).

5.7 Identify and Collect Required Data

For the equipment items listed in para. 5.4, the data needed to characterize the function and efficiency of the steam system should be identified, and values for these parameters and variables shall be determined in the course of the assessment. Essential data that should be acquired includes target variables in the applicable categories listed in paras. 5.7.1 through 5.7.4.

The specific data required will depend on the assessment goals. For example, if the goal is to examine the benefit of removing or adding one or more steam turbines, inlet and outlet steam conditions must be determined for these units.

If there are significant variations in steam system operation, values for target variables (e.g., boiler load) shall be determined at more than one point in time, or continuously for a period of time.

5.7.1 Temperature Measurements

(a) Boiler makeup water
(b) Boiler feedwater
(c) Ambient air
(d) Boiler stack gas (before and after heat recovery equipment)
(e) Boiler economizer inlet and outlet water
(f) Steam header(s)
(g) Turbine inlet and outlet
(h) Condensate at return tank
(i) Steam trap inlet and outlet
(j) Boiler shell
(k) Steam distribution piping
(l) Combustion and ventilation air openings
(m) Heat exchanger inlet and outlet

5.7.2 Pressure Measurements

(a) Steam header(s) and branch lines
(b) Use points before pressure reducing valves (PRVs)
(c) Condensate return tank
(d) Deaerator
(e) Turbine inlet and exhaust

5.7.3 Flow Measurements

(a) Boiler fuel (solid, liquid, or gas) input rates for each boiler
(b) Boiler steam output rate(s)
(c) Makeup water
(d) Blowdown (or measurements from which blowdown can be computed)
(e) Steam turbines
(f) End-use steam consumption

5.7.4 Chemical Measurements

(a) Boiler makeup water chemical content [e.g., dissolved solids (or related conductivity), chloride, silica, as appropriate for application]
(b) Boiler (post-treatment) feedwater chemical concentrations
(c) Boiler internal water chemical concentrations
(d) Tracer chemical concentrations (if needed to compute blowdown rate)
(e) Condensate chemical concentrations

5.7.5 Establish a Steam System Baseline. To completely define assessment conditions, it is necessary to establish the system(s) baseline through gathering relevant steam system energy use data. These data are the basis for the assessment and the basis for comparison with future steam system operating conditions. The assessment should record system operating conditions in a way that can be accessed in the future.

5.8 Develop Assessment Measurement Plan

The assessment team shall develop a measurement plan to ensure that data collected is accurate, precise, and repeatable under a specific set of operating conditions.

5.8.1 Measurement With In-Place Equipment. Data can be obtained from already-installed and operating measurement system(s). The calibration and precision of the in-place measurement equipment shall be ascertained and documented, as shall the accuracy and repeatability of the measurements obtained.

5.8.2 Measurement With Portable Equipment. Data can be obtained with the use of portable equipment provided by the facility or the assessment team. The calibration and precision of the portable equipment shall be ascertained and documented, as shall the accuracy and repeatability of the measurements obtained.

5.8.3 Values Determined by Estimation. In the case that the measurement point is inaccessible or presents a physical risk, estimates may be necessary. Such estimates shall be based on mass and energy balances around the desired measurement point or knowledge based on common practice (see para. 5.1.1). In the case that reasonable estimation of needed values cannot be made, the specific conditions precluding such estimates and the impact on the assessment must be specified in the final report (see section 6).

5.9 Wrap-Up Meeting and Presentation of Initial Findings and Recommendations

The final step in the on-site phase of the assessment is the presentation of initial findings and recommendations. This event shall be attended by representatives of plant management and all assessment team members. It is suggested that a facility employee should chair the wrap-up meeting and aid in presenting the assessment results to encourage "buy-in" and demonstrate ownership of the assessment process and results. During this meeting, outstanding questions from the assessment team should be addressed. Then, the tentative results of the assessment should be formally presented and should include a review of the current status of steam system energy efficiency, the assessment process used, and the recommended assessment measures with energy and cost savings projections. The results presented shall be qualified to be preliminary, subject to needed further analysis. The target dates for the delivery of a draft and final versions of the written report shall be set by mutual agreement.

6 ASSESSMENT DATA ANALYSIS

Analysis of collected data shall be either manual calculations or complex system analyses. For manual analysis (e.g., determination of boiler combustion efficiency from tables of stack temperature and excess O_2 values), the analysis results can, for example, be immediately determined at the site of raw data measurement. For complex system analyses, system level tool(s) shall be used to model steam system conditions and quantify potential savings opportunities. Variations in operational data (e.g., boiler firing rates) should be incorporated in the data analysis. Typical variations result from process (production) variations, seasonal variations, and facility modifications (e.g., plant expansion).

6.1 Identification of Energy-Saving Opportunities

Energy-saving opportunities shall be documented as identified throughout the assessment. The use of a checklist is recommended. Possible opportunities shall be evaluated for applicability in the categories listed below as a minimum (if indicated equipment is installed).

6.1.1 Boiler Operations

(a) Fuel alternatives
(b) Reduce operating pressure (saturated steam systems)
(c) Increase operating pressure (cogeneration systems)
(d) Reduce stack losses
  (1) Combustion management
  (2) Combustion air preheater
  (3) Conventional feedwater economizer
  (4) Condensing economizer(s)
(e) Reduce shell radiation and convection losses
(f) Improve boiler water quality and reduce blowdown rate
(g) Recover energy from blowdown
(h) Feedwater pumping
(i) Load distribution among multiple boilers
(j) Boiler shutdown
(k) Combustion fan power management

6.1.2 Turbine Applications

(a) Add/remove from service
(b) Reduce backpressure
(c) Efficiency improvement
(d) Substitution for pressure reducing valves or elimination of vent steam

6.1.3 Distribution System Losses

(a) Reduction of pressure drops
(b) Repair leaks
(c) Repair or replace failed steam traps
(d) Insulation improvements

6.1.4 End Use

(a) Reduce steam demand
(b) Insulate process equipment hot surfaces
(c) Modify process parameters
(d) Change primary energy resource (e.g., steam versus direct-fired heating)
(e) Repair leaks

6.1.5 Condensate Collection and Return

(a) Repair or replace failed steam traps
(b) Repair leaks
(c) Increase condensate recovery
(d) Recover flash steam

6.2 Analysis of Identified Energy Saving Projects

As specified in para. 6.1 above, manual or software-based analysis is required to determine values of key system variables (e.g., boiler combustion efficiency). In the case where analysis of prospective energy-saving measures incorporates system interactions (e.g., change in blowdown energy with change in process steam demand), a system level analysis shall be used. For each identified project, the estimated energy savings and associated energy cost savings shall be documented. The energy savings identified should be expressed in MMBtu/year and other energy units commonly used by plant personnel.

6.3 Steam System Baseline

The assessment shall define and develop a steam system baseline (see para. 5.7.5 and definition of baseline conditions).

7 REPORT 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) Steam system 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, products made at the plant, and how steam is used at the plant
(b) goals and scope of the assessment
(c) system(s) assessed and measurement boundaries used
(d) steam system 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, products made at the plant, and how steam is used 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. Depending on system complexity, an overall steam system schematic diagram may be presented to clarify the components of the assessed steam system and their interrelationships. 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) assessed. Depending on the system assessed, the discussion 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 shall be described, e.g., operating issues or constraints. 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. Key summary data necessary for data analysis shall be included in the body of the report. Additional raw data, observations, and supporting documents should be placed in an appendix for convenient access.

Assessment reporting shall include the identification of all fuels and energy inputs, use rate of each, and the conditions under which each fuel is used in individual boilers. The typical time variation in plant/facility operating patterns, boiler loads, and average and peak loads shall be reported. The historical records (for a minimum of 1 yr) of fuel and energy purchases including amounts and cost by billing period (e.g., month) shall be reported.

Reporting information will also include cogeneration equipment operating characteristics. The nominal operating conditions of the steam turbines as well as any gas turbines in the system will be identified. Purchased power (exported power) requirements will also be identified.

The assessment report shall give details on the consistency, repeatability, and reproducibility of the measurements made during the assessment.

7.2.6 Data Analysis. The report shall include the results of measurements and data analyses performed. Any significant analytical methods, measurements, observations, and findings shall be documented.

7.2.7 Steam System Baseline. The assessment report shall contain the baseline for the steam system. The method used to develop the annual steam system energy-use baseline shall be described.

The assessment report will clearly explain the basis for the energy savings estimates. There may be cases where plant performance is not at the baseline level, or is expected to change in the future. In some cases savings estimates may be based on the baseline; in others they may be based on other operating conditions or projections.

7.2.8 Performance Improvement Opportunities and Prioritization. The analysis shall quantify estimates of energy reduction and energy cost savings from identified performance improvement opportunities. Additional calculations may address other energy and nonenergy 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 changeover, and other actions that reduce energy consumption.

Details on performance improvement opportunities to be documented and reported shall include sufficiently detailed descriptions of the actions required for project implementation. To aid in the selection of projects for implementation, the assessment team shall prioritize the performance opportunities identified based on factors such as impact, importance, and feasibility.

Each of the energy-saving project opportunities identified during the assessment shall be thoroughly defined in the written report. Project details to be documented and reported shall include a sufficiently detailed description of the actions required for project implementation, estimates of the potential energy savings (typically on an annual basis) and a projection of the energy cost savings to be achieved. The methodology used to obtain the savings estimates shall be presented with assumptions clearly stated. To aid in the selection of projects for implementation, the assessment team should categorize the opportunities identified to be of 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)

The report shall also document systems that were evaluated even though no improvement opportunities were identified. This may include identification of boiler fuels (or steam generator waste heat source), boiler management (including combustion control), boiler operating efficiency, status of the steam distribution system (including steam leaks, trap losses and insulation issues), the identification and energy-use efficiency of processes and equipment using steam, etc.

7.2.9 Recommendations for Implementation Activities. Details on performance improvement opportunities shall include the next steps needed to move from the identified performance improvement opportunities to implementation of the listed measures. Methods for refining data analysis, for performing additional engineering studies, and for obtaining reliable implementation cost estimates should be addressed. Methods 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 screening or feasibility estimates and could also include preparing metrics such as return on investment, payback period, and potential greenhouse gas impacts.

It should be noted in the assessment report that it is recommended that further engineering analysis be performed prior to implementing the recommendations contained in the assessment report.

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. Raw data, observations, and supporting documents should be placed in appendices.

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 analysis results 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 U.S. DEPARTMENT OF ENERGY INDUSTRIAL TECHNOLOGIES PROGRAM (http://www1.eere.energy.gov/industry/)

A-1.1 Software Tools

Steam System Assessment Tool (SSAT), Version 3 (models of complete steam systems)
Steam System Scoping Tool (SSST) (screening tool)
3E Plus (insulation analysis)

A-1.2 Publications

Tip Sheets (two-page technical briefs with advice for improving steam system performance):
Benchmark the Fuel Cost of Steam Generation
Clean Boiler Water-side Heat Transfer Surfaces
Consider Installing a Condensing Economizer
Consider Installing High-Pressure Boilers with Backpressure Turbine-Generators
Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers
Consider Steam Turbine Drives for Rotating Equipment
Considerations When Selecting a Condensing Economizer
Cover Heated, Open Vessels
Deaerators in Industrial Steam Systems
Flash High-Pressure Condensate to Regenerate Low-Pressure Steam
Inspect and Repair Steam Traps
Install an Automatic Blowdown Control System
Install Removable Insulation on Valves and Fittings
Insulate Steam Distribution and Condensate Return Lines
Improve Your Boiler's Combustion Efficiency
Minimize Boiler Blowdown
Minimize Boiler Short Cycling Losses
Recover Heat from Boiler Blowdown
Replace Pressure-Reducing Valves with Backpressure Turbogenerators
Return Condensate to the Boiler
Upgrade Boilers with Energy-Efficient Burners
Use Feedwater Economizers for Waste Heat Recovery
Use Low Grade Waste Steam to Power Absorption Chillers
Use Steam Jet Ejectors or Thermocompressors to Reduce Venting of Low-Pressure Steam
Use Vapor Recompression to Recover Low-Pressure Waste Steam
Use a Vent Condenser to Recover Flash Steam Energy

Improving Steam System Performance: A Sourcebook for Industry (updated 12/04)

A-2 SELECTED RESOURCES AND TOOLS LISTED IN THE SOURCEBOOK

Boiler Plant and Distribution Optimization Manual, Association for Facilities Engineering (AFE), Cincinnati, OH (www.afe.org)
Steam: Its Generation and Use, Babcock and Wilcox, Barberton, OH (www.babcock.com)
Steam Efficiency Improvement, Boiler Efficiency Institute, Auburn, AL (www.boilerinstitute.com)
Energy Efficiency Handbook, Council of Industrial Boiler Operators (CIBO), Burke, VA (www.cibo.org)
Efficient Boiler Operations Source Book, F. W. Payne and R. E. Thompson (4th Edition), The Fairmont Press, Lilburn, GA (www.fairmontpress.com)
The Steam Trap Handbook, J. F. McCauley, The Fairmont Press, Lilburn, GA (www.fairmontpress.com)
Handbook of Thermal Insulation Design Economics for Pipes and Equipment, W. C. Turner and J. F. Malloy, Krieger Publishing Company, Melbourne, FL (krieger_publishing.com)
Marks' Standard Handbook for Mechanical Engineers, E. Avallone and T. Baumeister III (Editors), McGraw-Hill, New York, NY (www.bookstore.mcgraw-hill.com)
Nalco Water Handbook (2nd Edition), Nalco Company, Naperville, IL (www.nalco.com)
Steam Utilization — Design of Fluid Systems, Spirax Sarco Applications Engineering Department, Blythewood, SC (www.spiraxsarco.com)
Steam Trapping Principles, TLV Company, Ltd., Charlotte, NC (www.tlv.com)
ASME PTC 39, Steam Traps, American Society of Mechanical Engineers (ASME), New York, NY (www.asme.org)
Steam Trap Testing Guide for Energy Conservation, Armstrong International, Inc., Three Rivers, MI (www.armintl.com)

National Commercial and Industrial Insulation Standards, National Insulation Association (NIA), Alexandria, VA (www.insulation.org)

Steam Distribution, Technical Reference Guide (TR-GCM-03), Spirax-Sarco Applications Engineering Department, Blythewood, SC (www.spiraxsarco.com)

Industrial Water Treatment Procedures, PWTB 420-49-5, U.S. Army Corps of Engineers, Washington, D.C. (www.usace.army.mil)

PROSTEAM software, Linnhoff March, Northwich, Cheshire, United Kingdom (www.linnhoffmarch.co.uk)

ESteam (software modeling tool), Veritech Corporation, Sterling, VA (www.veritech-energy.com)

A-3 OTHER REFERENCES

ANSI/MSE 2000:2008, A Management System for Energy, Georgia Institute of Technology, 2008

ASME PTC 4, Fired Steam Generators, American Society of Mechanical Engineers

ASME EA-3–2009

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