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# **Energy Assessment for Pumping Systems**

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**AN AMERICAN NATIONAL STANDARD**



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Mechanical Engineers**



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**ASME EA-2-2009**

# **Energy Assessment for Pumping Systems**

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**AN AMERICAN NATIONAL STANDARD**



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# CONTENTS

Foreword .....	iv
Committee Roster .....	v
Correspondence With the EA Committee .....	vi
<b>1        Scope and Introduction .....</b>	<b>1</b>
<b>2        Definitions .....</b>	<b>2</b>
<b>3        References .....</b>	<b>3</b>
<b>4        Organizing the Assessment .....</b>	<b>4</b>
<b>5        Conducting the Assessment .....</b>	<b>6</b>
<b>6        Analysis of Data From the Assessment .....</b>	<b>13</b>
<b>7        Reporting and Documentation .....</b>	<b>15</b>
<b>Figures</b>	
1        System Assessment Approach .....	1
2        Components of a Pumping System Assessment Logic Diagram .....	8
<b>Table</b>	
1        Assessment Level Overview .....	7
<b>Nonmandatory Appendices</b>	
A        Key References .....	19
B        Prescreening Worksheet .....	20

# FOREWORD

This document provides a standardized framework for conducting an energy assessment of pumping systems, hereafter referenced as an “assessment.” A pumping system is defined as one or more pumps and those interacting or interrelating elements that together accomplish the desired work of moving fluid. A pumping system thus generally includes pump(s), driver, drives, distribution piping, valves, sealing systems, controls, instrumentation, and end-use equipment such as heat exchangers. 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 various techniques such as measurement, resulting in the identification, documentation, and prioritization of energy performance improvement opportunities.

This Standard sets the requirements for conducting and reporting the results of an assessment that considers the entire system, from energy inputs to the work performed as the result of these inputs. An assessment complying 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, commercial, and municipal sectors.

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

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

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

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

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

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

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

ASME EA-2–2009 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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- 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.
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# ENERGY ASSESSMENT FOR PUMPING SYSTEMS

## 1 SCOPE AND INTRODUCTION

### 1.1 Scope

This Standard covers pumping systems, which are defined as one or more pumps and those interacting or interrelating elements that together accomplish the desired work of moving a fluid. A pumping system thus generally includes pump(s), driver, drives, distribution piping, valves, sealing systems, controls, instrumentation, and end-use equipment such as heat exchangers. This Standard addresses open and closed-loop pumping systems typically used in industry, and is also applicable to other applications.

This Standard sets the requirements for conducting and reporting the results of a pumping system assessment (hereafter referenced as an “assessment”) that considers the entire pumping 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 subsystem within an industrial facility with equal weight; however, it must be sufficiently comprehensive to identify the major efficiency improvement 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 institutional, commercial, and water and wastewater facilities.

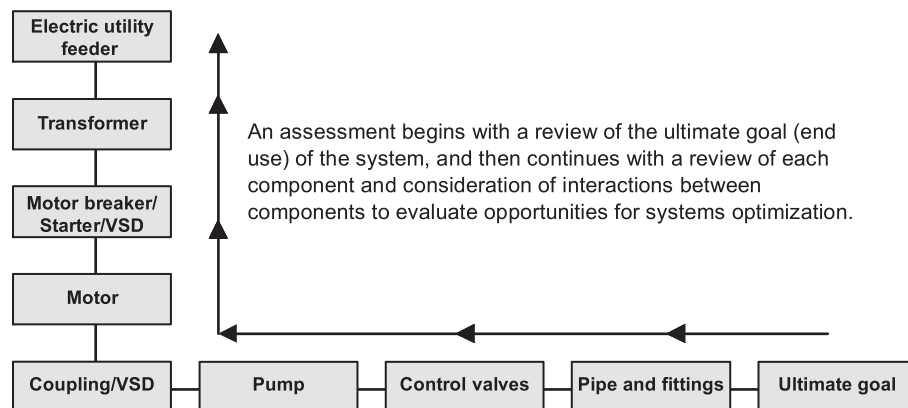
Assessments involve collecting and analyzing system design, operation, energy use, and performance data,

and identifying energy performance improvement opportunities for system optimization. An assessment may also include other 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). Assessment activities may 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 implementation in a written report. This report should document system design; quantify energy consumption and performance data; document the assessment process; show results, recommendations and savings projections; and improve facility personnel’s understanding of system energy use and operation.

All system assessments start with identifying the ultimate goal of the system. When the ultimate goal of the system has been established, the assessment continues to investigate how well-suited the existing system is to deliver the needed output from the perspective of both component selection and energy efficiency. See Fig. 1. An assessment thus encompasses more than just looking at input and output of energy.

This Standard sets requirements for: organizing and conducting a pumping system assessment; analyzing the data from the assessment; and reporting

**Fig. 1 System Assessment Approach**



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.

This Standard differentiates between and has requirements for three levels of assessments:

(a) Level 1 (prescreening) assessment is a qualitative investigation that is intended to determine the magnitude of energy optimization potential and therefore determine the necessity for a Level 2 or Level 3 assessment. The Level 1 assessment is used to identify specific systems for further analysis. A Level 1 study may be performed prior to beginning the Level 2 or Level 3 study. Alternately, a Level 1 assessment may be performed in concert with the Level 2 or 3 assessments. In this case, if a given pumping system does not pass the prescreening criteria indicating a Level 2 or Level 3 assessment is required, the assessment process for that pumping system is considered complete.

(b) Level 2 assessment is a quantitative (measurement-based) investigation meant to determine the energy savings potential for at least one operating condition. This assessment is performed using data taken from the plant information systems or by using portable measuring devices. The measurements usually cover a limited amount of time, thus giving a snapshot of the operating conditions at the time of measurement. In systems with little or no variability, a Level 2 assessment shall be used to determine the savings potential.

(c) Level 3 assessment is also a quantitative investigation, requiring measurements taken over an extended period of time sufficient to develop a system load profile. This activity is usually associated with more extensive use of in-situ monitoring to ensure that the operating conditions can be accurately determined at the various duty points. The data analysis is also more complex.

All pumping system assessments should start with a Level 1 assessment. During this prescreening, the pumping systems that will undergo further investigation are identified and selected. The outcome of the prescreening process shall be the selection of the best candidates, typically those with significant energy savings potential, for more in depth analysis (Level 2 or Level 3 assessment). The assessment team shall determine which systems require a Level 2 or Level 3 assessment based on the criteria presented in section 5. An overview of the decision making process for each of the levels are provided in Fig. 2 (see para. 5.2).

## 1.2 Limitations

This Standard does not provide guidance on how to perform a pumping system assessment, but sets the requirements that need to be performed during the system assessment. For additional assistance, see the companion

*ASME Guide for ASME EA-2-2009 Energy Assessment for Pumping Systems* on how to apply this Standard.

(a) This Standard does not specify how to design a pumping 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 requirements for an implementation action plan.

(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, security, 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 system which consider all components and functions, from energy inputs to the work performed as the result of these inputs. Individual components or subsystems may not be addressed with equal weight, but system assessments must 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.

*best efficiency point (BEP)*: the rate of flow and head at which the pump efficiency is at its maximum for a given operating speed.

*bypass control*: bypassing flow from the discharge to the suction side of the pump through a special conduit.

*cavitation*: a phenomenon in which the local pressure drops below the vapor pressure of the fluid, resulting in the liquid flashing to vapor, but with subsequent pressure recovery, resulting in the vapor pockets violently collapsing back to the liquid state. This can occur within the pump or at other locations in the system.

*centrifugal pump*: the most common type of rotodynamic pump. Rotodynamic pumps are kinetic machines in

which energy is continuously imparted to the pumped fluid by means of a rotating impeller, propeller, or rotor. The most common types of rotodynamic pumps are centrifugal (radial), mixed flow, and axial flow pumps. Centrifugal pumps use bladed impellers with essentially radial outlet to transfer rotational mechanical energy to the fluid primarily by increasing the fluid kinetic energy (angular momentum) and also increasing potential energy (static pressure). Kinetic energy is then converted into usable pressure energy in the discharge collector.

*design point*: the calculated operating point for a pump during the design phase of a project. This point usually deviates from the actual operating point.

*duration diagram*: a diagram showing the amount of time that the value of a parameter exceeds a certain value, i.e., the flow is higher than  $Q_a$  for 3,000 hr/yr.

*duty point*: a specific pump total head and rate of flow condition.

*fluid power*: the power imparted to the fluid by the pump.

*histrogram*: a graphical display of the distribution frequency of intervals of flow rate, head, power, or other parameters, such as valve position.

*operating efficiency*: pump efficiency at a given operating point.

*performance curves*: x-y graph type plots of head, shaft power, and/or efficiency and net positive suction head required as a function of flow rate. The terms *performance curves* and *pump curves* are commonly used interchangeably.

*plant information system*: plant computer system where relevant process information is monitored and stored.

*power factor*: a measure of how the voltage leads or lags the amperage.

*prescreening*: sorting systems according to anticipated saving opportunities.

*pump curves*: see *performance curves*.

*pump efficiency*: the ratio of the pump output power to the pump input power; i.e., the ratio of the fluid power to the brake horsepower, expressed as a percentage.

*pumping system*: a pump or group of pumps and the interacting or interrelating elements that together accomplish the desired work of moving fluid. The system usually includes (but is not necessarily limited to) the pump, driver, drives, and those piping and valve elements that transfer and control the flow and hydraulic energy from the pump.

*pumping system efficiency*: the minimum hydraulic power needed to fulfill the process demands divided by the input power to the pump drive system.

*qualified personnel*: personnel qualified to perform specific tasks required for an assessment and understanding the requirements of this Standard.

*shaft input power*: the amount of power delivered to the shaft of a driven piece of equipment.

*system*: logical group of energy-using industrial equipment organized to perform a specific function.

*system boundary*: the parts of a system that should be investigated during the assessment process fall inside the system boundaries. Other parts might be connected to the system but are not included in the assessment. Such parts could, however, influence the overall goal or purpose of the system. The assessment team determines the proper system boundaries as well as the points at which efficiency measurements should be made.

*system curve*: a curve indicating the head required to achieve a certain flow rate through a system for a fixed set of system conditions, including liquid levels, gas or vapor overpressure, and valve positions. The pump operates where the system curve intersects the pump curve.

*throttle*: a device (normally a valve) that is used to increase the frictional resistance as a means to control flow rate.

*total dynamic or differential head*: the measure of energy per unit weight of liquid, imparted to the liquid by the pump. This can be described as an increase in height of a column of liquid that the pump would create if the static pressure head and the velocity head were converted without loss into elevation head at their respective locations.

*variable frequency drive (VFD)*: an electronic device designed to control the rotational speed of an alternating current (AC) electric motor by controlling the apparent frequency and voltage of the electrical power supplied to the motor. Also referred to as an adjustable frequency drive.

*variable speed drive (VSD)*: any device that varies the speed of the pump, either mechanically or electrically. Also referred to as an adjustable speed drive.

### 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 about pumping 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. A number of 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. Additional assessment team member information is identified in para. 4.8.1.

#### 4.1.1 Required Personnel Responsibilities

##### 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 Pumping 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 pumping system.
- (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 Resources and Information

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

- (a) facility areas and pumping systems required to conduct the assessment
- (b) facility personnel (engineering, operations, maintenance, etc.), their equipment vendors, contractors, and others, to collect information pertinent and useful to the assessment activities and analysis of data used for preparation of the report
- (c) other information sources, such as drawings, manuals, test reports, historical utility bill information, computer monitoring and control data, electrical equipment panels, and calibration records

### 4.5 Assessment Goals and Scope

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

### 4.6 Initial Data Collection and Evaluation

Initial data collection occurring before the start of the assessment will save time for the assessment effort and should include but not be limited to the items in paras. 4.6.1 through 4.6.4.

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

**4.6.2 Energy Project History.** The assessment team shall collect and review information on energy-saving projects, assessments, audits, baselines, or benchmarking already conducted for the pumping systems.

**4.6.3 Primary Energy Cost.** The cost data shall include values in terms of units such as cost per kWh, or other similar terms, considering all charges such as demand charges, peak rates, time-of-the-day rate and any other costs up to the point of use. Where necessary, appropriate costs should be assigned to on-site generated electricity. These costs should be used in subsequent analyses. The assessment team shall agree on the period during which the costs would be considered valid. Although average values are appropriate in most cases, the assessment team should also consider issues such as demand charges and trends to identify situations not made obvious by the use of averages.

A facility may have already established a marginal cost for energy. If not, an agreed-upon marginal cost or other cost method shall be developed for use in calculating an annual energy cost.

**4.6.4 System Data.** The assessment team shall

- (a) define the system(s) function and boundaries
- (b) identify high energy use equipment
- (c) identify control method(s)
- (d) identify inefficient devices (obvious signs of disrepair or incorrect operation)
- (e) initial measurement of key system operating variables, if possible

## 4.7 Site-Specific Goals

Based on preliminary data collection and evaluation, site-specific goals shall be developed. Pumping systems, the industries they serve, and end-use applications are very diverse. As a result, the goals of a pumping system assessment vary from system to system. The assessment team shall determine assessment goals and develop the statement of work for the assessment.

The assessment team shall develop the assessment goals as they apply to the facility. These goals should be consistent with the organizational goals identified in para. 4.5, together with information about the present pumping systems and stakeholder needs developed in para. 4.6. An overall goal of the assessment shall include identification of performance improvement opportunities in the selected pumping systems, and may include auxiliary systems and components as determined by the assessment team. These auxiliary systems and components may include valves, sealing systems, controls, etc.

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

## 4.8 Assessment Plan of Action

To facilitate the assessment and to make it clear to all assessment team members how the assessment will

be conducted, it is essential that an action plan for the assessment be developed and agreed upon. Figure 2 (see para. 5.2) shows the activities necessary during the assessment and the sequence in which they should be made. 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) establish information goals
  - (1) Review information that has been collected before the start of the assessment.
  - (2) Identify how much is known about the systems and what information has to be obtained.
  - (3) Start with a Level 1 assessment. See para. 5.2.1.
- (b) identify informational objectives for the assessment (see paras. 5.1 and 5.2)
  - (1) Determine how extensive the assessment will be.
  - (2) Identify the systems that are going to be included in the assessment.
  - (3) Identify what information is available and what is necessary to collect.
  - (4) Identify information that is available on paper records (such as logs) or in the plant computer systems and what system parameters are necessary to measure.
  - (5) Identify who is going to be involved and responsible for the collection of necessary data.
- (c) establish measurement requirements (see paras. 5.1 and 5.6)
  - (1) Identify whether a snapshot of the conditions is sufficient (Level 2) or if it is necessary to collect information during an extended period of time (Level 3).
- (d) Identify if permanently installed measurement equipment is available and trustworthy.
- (e) identify additional informational objectives (see paras. 5.3 through 5.5)
  - (1) A list of information to collect is found in para. 5.3.
  - (2) Identify the true process demands. See para. 5.4.
  - (3) Identify the system boundaries. See para. 5.5.
- (f) identify the study method required to meet assessment informational objectives
  - (1) Identify how the data are going to be analyzed. See para. 6.2.
  - (2) Identify tools/software programs that are going to be used.
- (g) identify content of the report and responsibilities (see section 7)

**4.8.1 Identification of Other Assessment Team Members Required.** If the assessment is to be successful, one or several "system owner(s)" or champion(s) shall be selected. These persons could be one and the same but usually are not. Pumps usually serve a process or other end use that is managed by process specialists or operations personnel.

Due to the large variation in structure, size, and function of organizations, the make-up of personnel on the assessment team may vary. It is, however, advantageous if the following additional roles are represented:

(a) One or more “system owners” who can be developed into a “pump champion” or “energy champion.” Large organizations may have so many pumping systems that it is impossible for one person to know them all. Therefore, several persons from this category may represent different parts of the facility. At smaller facilities, the “champion” may also be the appropriate “champion” for other energy areas.

(b) One or more process or operations personnel who rely on the system(s). In some cases the pump systems are subsystems to a larger system. In such cases personnel with a good understanding of the larger system should be available or on the assessment team.

(c) One or more pumping system operators.

The participants in the assessment team should be chosen prior to the development of the plan of action. The assessment team should be briefed before the assessment so that minimal time has to be devoted to explaining the purpose and execution of the assessment. The facility must choose the participants on the assessment team, but the assessment team must also have access to facilities personnel who understand connected systems that will be influenced by changes made to the pumping system. Since large facilities could have several processes that are assessed, different persons representing such processes could be involved in the portions of the assessment that concern their system only.

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

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

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

The on-site assessment activities will conclude with a wrap-up meeting designed to outline the assessment investigations and initial recommendations. This meeting is discussed in para. 5.9.

**4.8.3 Key Personnel Interviews.** Subject to modification during the course of the assessment, the dates and

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

## 4.9 Goal Check

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

# 5 CONDUCTING THE ASSESSMENT

## 5.1 Introduction

Pumping systems vary tremendously between different types of industries and facilities. A municipal system might contain ten pumps whereas a large paper mill might have several hundred pumps installed.

Some facilities have a large number of pumping systems and it is unrealistic to assess all pumping systems. Additionally, it may not be cost-effective to assess certain systems, such as small-capacity systems or systems that run infrequently. It is therefore essential that a prescreening be made of the installed systems so efforts can be concentrated where the savings potential is greatest.

Different systems also require different amounts of effort and expertise to be assessed. Therefore, this Standard defines three levels of assessments for pumping systems.

This Standard does not describe how all systems in a facility are assessed but does describe the different levels of assessment and how to assess an individual system. This Standard does discuss how to prioritize the pumping systems with the greatest energy-savings potential. The systems to be considered (the scope of the assessment) shall be determined during the initial contacts between the facility and the assessment team.

One facility may contain pumping systems that need the effort of either one or more of the levels described in para. 5.2. As the facility is being assessed, part of the outcome of Level 1 and Level 2 assessment is whether the system needs to be brought to the next higher level of assessment.

In some cases a pumping system is a subsystem of a larger system and it will be impossible to optimize the pumping system without having a clear understanding of how the larger system is affected by changes made to the pumping system. In such cases it may be necessary to connect with persons with knowledge about the larger system to determine the constraints the larger system puts on potential modifications to the pumping system.

Table 1 gives a summary of the different assessment levels.

**Table 1 Assessment Level Overview**

<b>Activities</b>	<b>Level 1 Assessment</b>	<b>Level 2 Assessment</b>	<b>Level 3 Assessment</b>
Prescreening opportunities	Req.	n/a	n/a
Walk through	Opt.	Req.	Req.
Identify systems with potential saving opportunities	Req.	Req.	Req.
Evaluate systems with potential saving opportunities	Opt.	Req.	Req.
Snapshot type measurement of flow, head and power data	Opt.	Req.	n/a
Measurement/data logging of systems with flow conditions that vary over time [Note (1)]	n/a	n/a	Req.

NOTE:

(1) Verify and use data from plant historical information where applicable.

## 5.2 Assessment Levels

There are different levels of assessment, and different systems require varying work efforts to assess their effectiveness. There are cases when a rudimentary analysis can show possible savings, i.e., more pumps are running than necessary and it is easy to calculate savings by turning unnecessary pumps off. This can be determined during a Level 1 assessment. Level 1 also prescreens pumps to determine if a Level 2 or Level 3 assessment is required. The next level, Level 2, is when system conditions are stable and a snapshot of the performance data is enough to calculate the saving opportunities. The most demanding case, Level 3, is when there are large changes in system demand over time and the system in question has to be monitored over a longer period of time. See Fig. 2.

The specific data and actions required for these three levels are considerably different in magnitude — and the effort required to acquire and implement can also vary within an individual level. For example, a system that already has installed flow and power meters that provide accurate data would be much more easily dealt with in a Level 2 assessment than one that has neither. Likewise, for a Level 3 assessment, if the facility already has a database of historical flow rates, valve positions, pressures, etc., the need for temporary data logging can be significantly reduced.

The activities that comprise the Level 1 prescreening, policies, and practices shall be applied to all plant systems reviewed. While individual system symptoms (in prescreening) and component features (policies and practices) are considered, the breadth of equipment covered in these areas will be such that it is generally not practical to take system level details into account. When a system undergoes a Level 2 or Level 3 assessment, it is analyzed and treated on a detailed, system-level basis. Alternatively, when a system undergoes a Level 1 assessment, it is only afforded policy/practice consideration.

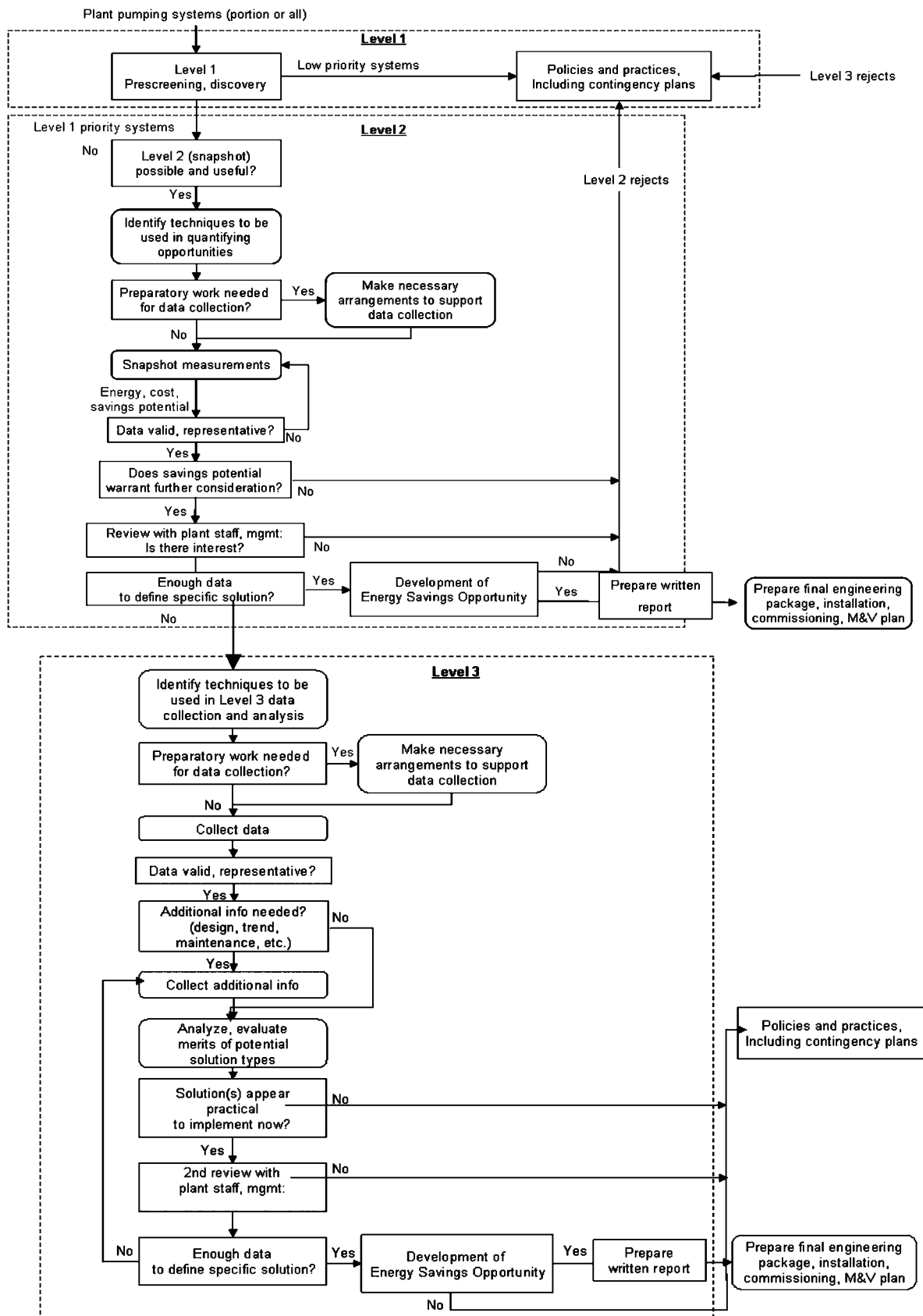
For a system in which a change cannot be justified at present, but might as circumstances change, the policies and practices arena should include an evaluation process. This process should determine whether the extent of the potential savings justifies preparatory work (such as detailing actions to take in the event of a component failure).

**5.2.1 Level 1 Assessments.** A Level 1 assessment should include gathering of system information for pumping systems considered for evaluation within the scope of the assessment. Prescreening shall include listing of these pumping systems operated within the facility, including the motor nameplate power, hours of operation, and pump function. During the prescreening, the control methods for the different systems shall be noted. During the prescreening, it shall be determined which systems are best suited for a closer evaluation. It should also be noted if changes to the pump system will affect other systems, thereby introducing constraints on potential optimization strategies for the pump system.

For some plants, instead of prescreening all pumping systems, only those pumping systems larger than a predetermined minimum size and with significant operating hours, or systems with annual operating costs over a set minimum, should undergo a Level 1 assessment, as set by the assessment scope.

Noncentrifugal pumping systems and systems with limited operating hours should also be used as criteria for excluding specific systems from the assessment studies.

As much information as practical should be collected during the Level 1 assessment. Essential data is listed below. Some data listed under optional information may eventually be required, but is not necessary to collect upfront.

**Fig. 2 Components of a Pumping System Assessment Logic Diagram**



A proper prescreening and interview by the assessment team can save considerable time during the assessment by identifying constraints, known deficiencies, and other important information.

The availability at the plant of some types of data (see paras. 5.2.1.1 and 5.2.1.2) should also be reported during the Level 1 assessment even if it is not collected.

A prescreening worksheet shall be used to assist in this prescreening exercise. Nonmandatory Appendix B contains an example worksheet to aid in the data collection process.

In general, the steps taken during the prescreening shall include the following:

- (a) Sort by system size, annual operating hours, and estimated energy cost.
- (b) Focus on centrifugal pumps operating at fixed speed.
- (c) Focus on pumping systems that throttle, recirculate, or by-pass for flow control.
- (d) Look for energy-waste symptoms such as large difference in supply and demand, commonly achieved through valve throttling and by-pass flows (see para. 5.4).
- (e) Identify inefficient pumping systems via maintenance and operational staff interviews and review of maintenance records.
- (f) Select for assessment those systems that appear most likely to exhibit savings potential.

From this information the assessment team shall make estimates regarding the potential for energy savings in each system and shall select the pumping systems that meet the criteria for Level 2 or Level 3 assessments.

#### 5.2.1.1 Required Data

- (a) Description of the facility
- (b) Pumping system inventory (provided prior to assessment start) for systems that meet prescreening criteria
  - (1) List of pumps
  - (2) Pump description (including pumped media)
  - (3) Pump type
  - (4) Pump application
  - (5) Physical location of pump
  - (6) Installed motor data (rated nameplate power, voltage, full load amperage, and frequency)
  - (7) Annual operational hours (or % operation)
  - (8) Control method (e.g., control valve, VSD, bypass)

#### 5.2.1.2 Optional Information

- (a) Operating parameters (including flow and pressure)
- (b) Pump curve(s)
- (c) Design point
- (d) Cavitation at pump or in system
- (e) Maintenance level (low, medium, high)
- (f) Equipment information (service type, time in service, shared duty, voltage)
- (g) Typical flow rates and variations thereof
- (h) Duration diagrams

- (i) Histograms
- (j) Maintenance costs
- (k) Process & Instrument Diagrams (P&ID)/Digital Control System (DCS) screen-shots
- (l) Rating of any steam turbine drive

**5.2.2 Level 2 Assessments.** Level 2 and Level 3 assessments are quantitative (measurement-based) investigations to determine the energy savings potential of systems and include measurement of system variables. The difference between Level 2 and Level 3 assessments is the complexity of data gathering and, later on, the evaluation of the collected data.

Level 2 assessments shall be performed using data taken from the plant information systems, in paper or electronic format, or by using portable measuring devices. The measurements usually cover a limited amount of time, thus giving a snapshot of the operating conditions at the time of measurement.

In some cases a Level 2 assessment of the system is enough to determine the operating system efficiency and the savings potential. This is the case when it is clear that the observed operating conditions are representative for the operation of the systems and the changes in operating condition are small or nonexistent.

In some cases the pumping system can be fairly simple and straightforward, but the assessment is complicated due to influence on other systems that sets constraints on the possible changes to the pumping system.

**5.2.3 Level 3 Assessments.** Level 3 assessments shall be made on pumping systems where conditions vary substantially over time. In such systems, the assessment team shall measure system performance over a time period long enough to capture all operating conditions. This activity is usually associated with more extensive use of in-situ monitoring to ensure that the operating conditions can be accurately determined at the various duty points (i.e., design point, normal, maximum and minimum flow rates). The monitoring can be made by connecting transducers to data logging equipment and recording the sensor output, or in some plants, where historical information is stored, the relevant information might be downloaded from the plant information system.

### 5.3 Walk-Through

After the prescreening has been conducted and systems have been selected for further investigation, the assessment normally starts with a visual examination of each pumping system to be assessed under Level 2 or Level 3. This shall entail walking the systems from start to finish ensuring that the information provided to the assessment team reflects the configuration of the existing systems.

It is advantageous to have an accurate piping and instrumentation diagram (P&ID) (if available) or other graphical description that represents flows, pressures, and all components and accessories of the existing system.

As process requirements change over time, systems evolve as well. Beware that the as-built documentation may be out-of-date. All components of the system shall be considered and pertinent information such as valve locations, locations of available pressure taps, flow meters, valve positions, etc., should be noted.

A walk-through is required for Level 2 and Level 3 assessments and may be required for some pumping systems undergoing a Level 1 assessment. When the facility owner is confident that the provided information, such as P&ID and other drawings, accurately represent the target system, this step may not be required.

During the walk-through, information about the control methods for the different systems such as valve settings should be noted.

For the pumping systems undergoing Level 2 and Level 3 assessments, after the walk through is completed, the data listed in para. 5.6 shall be collected using the methodologies specified in para. 5.7.

(a) The assessment team shall also identify any existing conditions that are often associated with inefficient pumping system operation. These conditions include indicators such as

- (1) pumping systems where significant throttling takes place
- (2) pumping systems with recirculation of flow used as a control scheme
- (3) pumping systems with large flow or pressure variations
- (4) multiple pumping systems where the number of operated pumps is not adjusted in response to changing conditions, or operating with excessive lead/lag cycling
- (5) systems serving multiple-end uses where a minor user sets the pressure requirements
- (6) cavitating pumps and/or valves
- (7) high vibration and/or noisy pumps, motors or piping
- (8) pumping systems with flow or head that have degraded over time due to wear on pump impellers and casings, clogged piping, or other reasons (may require consulting facility staff and historical data)
- (9) pumps with high maintenance requirements
- (10) systems for which the functional requirements have changed with time, but the pumps have not

(b) Other items that should be noted include the following:

- (1) Valves should be examined to confirm that they are operational.
- (2) The assessment team should gather pump and drive-motor nameplate information and document operating schedules to develop load profiles, then obtain head/capacity curves (if available) from the pump man-

ufacturers to document the pumping system design and operating points.

(3) The assessment team should determine current motor rewind policies and practices used by the plant. If best practices for rewinding motors are not followed, the motor losses could be larger than indicated by the manufacturers' data.

(4) The assessment team should also note the system flow rate and pressure requirements, pump style, operating speed, number of stages, and specific gravity, temperature, and viscosity of the fluid being pumped. If possible, the assessment team should also measure and note the flow rate and the suction and discharge pressures. (Note that spot checks of in-situ flow rates may only represent one point in time where demand varies on a continuous basis.)

(5) The assessment team should examine the condition of sealing systems, especially on high temperature applications and applications with a high ingress of fluid into the pump process fluid.

## 5.4 Understanding System Requirements

The assessment team shall determine the functional requirements of each pumping system undergoing a Level 2 or Level 3 assessment. To assess a system, it is imperative to understand the required function of the system. This is sometimes referred to as the ultimate goal of the system, which describes all the necessary and desirable functions of the system. The assessment team must understand normal operating conditions as well as operation under extreme and upset conditions, knowing the limits within which the system is designed to operate and understanding how the operating conditions are distributed over time. Information about these parameters is often available in facility computer monitoring systems, or can often be obtained from engineers and operators familiar with the system.

When the pumping system is a subsystem to a larger system, the larger system may impose limits on potential optimization strategies. It may even be impossible to optimize the pumping system without fully understanding how the larger system is influenced by changes to the pumping system. In such cases the assessment team has to ensure that cross-functional expertise is represented on the assessment team so that all potential implications of a change are understood.

Some facilities may not have accurate records and the facility personnel may be unable to supply the needed information. The assessment team should monitor the system over some period of time in order to establish the demands on the system.

## 5.5 Determining System Boundaries and System Demand

The assessment team shall determine the system boundaries and system demand of each pumping system

undergoing a Level 2 or Level 3 assessment. A pumping system assessment considers the overall efficiency of an existing operating system. The system is typically made up of several components that may include, but are not limited to, the pump(s), driver, including the power supply system, variable speed control, piping, all valve types, fittings, and suction and discharge sources such as tanks, heat exchanger, boilers, etc. It is necessary to understand the subsystems role relative to the total plant process. The system boundary can be very complex as the subsystems may be part of a larger plant system, but the boundary shall be determined prior to any measurements and calculations.

The overall design of the system has a major influence on system efficiency. Pump efficiency is determined by the pump's operating point on its curve, whereas the system efficiency requires comparing the power necessary to fulfill the system demand to the input power to the system. In the case of pumping systems, input power is the power delivered to the system. If a variable frequency drive (VFD) is included in the system, it should be the power delivered to the VFD. For a system with no VFD, the input power is the power delivered to the motor.

There are usually large differences between optimum efficiency of a component (such as a pump's best efficiency point), operating efficiency of the same component, and finally system efficiency. When system efficiency is calculated, the fluid power necessary to fulfill the process demand, not the fluid power produced by the pump, shall be used.

The purpose of performing a pumping system assessment is to identify opportunities to reduce energy consumption or energy intensity of the system. To do this, the assessment team first has to determine the system demand. For a simple throttled system, the system demand is the head and flow downstream of the throttling valve. For a bypass-controlled system it is the flow that is not bypassed and the appropriate pressure. The true system demand can be difficult to determine for more complex systems, and system demand can vary due to process/production requirements as well as seasonal changes.

Occasionally, factors outside the investigated system may influence the system or its operation. Such factors could originate from the ultimate goal of the system.

## 5.6 Information Needed to Assess the Efficiency of a Pumping System

Pumping system efficiency incorporates the efficiencies of the pump, motor, and other system components. A goal of the Level 2 and Level 3 assessments is to compare the used energy to the minimum that is required to meet the process demands. Typical data collection needs for a Level 2 or Level 3 assessment are provided below.

Note that not all data must be collected in all cases to perform a proper assessment. The assessment team shall determine the data collection needs for each system being evaluated.

The assessment team shall maintain quality assurance in the design and execution of a measurement plan as a consistent, repeatable, and reproducible process. The measurement plan shall adhere to principles of accuracy, transparency, and reliability. The assessment team should estimate the confidence, precision, and data loss of measurements. The measurement plan shall include the measurements required to develop an annual energy consumption baseline for the pumping system.

**5.6.1 Driver Information.** It is recognized that there are different types of drivers installed in industrial facilities, such as various kinds of electrical motors, steam turbines, belt drives and variable speed drives. This standard is focused on assessing electrically driven pumping systems, which are dominant in most industrial facilities.

For assessments regarding the efficiency of a steam turbine, the reader is referred to the *Energy Assessment for Steam Systems* standard (ASME EA-3).

It should also be noted that it is not necessary to know the exact driver efficiency to estimate unnecessary losses in a pumping system. The loss estimation method is described in para. 6.2.2.

**5.6.1.1 Motor Information.** Initial motor/drive information to be collected from the nameplate (if available) or manufacturer data sheets includes

- (a) line frequency
- (b) motor size (rated power)
- (c) motor rated speed — synchronous and full-load revolutions per minute (RPM)
- (d) motor rated voltage
- (e) motor full-load amps (FLA) — the current to the motor when operating at rated power
- (f) nominal efficiency or efficiency class (if provided)
- (g) motor type (NEMA design)
- (h) service factor
- (i) direct drive or belt

**5.6.1.2 Steam Turbine Drivers.** In systems where a steam turbine is used to drive a pump, the pumping system boundary can be drawn in such a way that the turbine is covered by ASME EA-3 and the rest of the system by this Standard. This Standard does not address the assessment of steam turbines.

**5.6.2 Pump Information.** This information should be obtained from the pump nameplate (if available) and any records that may be kept on file for the pump. If the information from the nameplate and records differ, this should be noted and addressed later in the assessment of

the system. Pump information required (when available) includes

- (a) type of pump
- (b) number of stages
- (c) type of drive
- (d) nominal speed — (RPM)
- (e) design point (QH) — “Q” represents “flow” and “H” represents “head”
- (f) impeller diameter
- (g) pump performance curve, if available (including rated discharge head, flow and iso-efficiency lines)
- (h) maintenance records
- (i) note any pump cavitation

**5.6.3 Fluid Properties Information.** Required fluid information, such as

- (a) viscosity
- (b) temperature
- (c) specific gravity
- (d) presence of solids and their characterization

**5.6.4 Measured Data.** This data is gathered utilizing facility instrumentation or other diagnostic tools that the facility or assessment team may have available.

**5.6.4.1 Electrical Data.** Required electrical data includes

- (a) actual motor voltage
- (b) current or power

**5.6.4.2 Fluid Data.** Required fluid information includes

- (a) flow rate.
- (b) pressure data at different locations in the system. Pump operating efficiency is determined by measuring flow and head delivered by the pump and comparing the fluid power to the power input to the motor/drive. To determine system efficiency, the input to the motor/drive is compared to the lowest amount of energy that satisfies process demands. Pressure measurements therefore have to be made at such points in the system that enables calculating the process demands. For example, in throttled systems the system demand is represented by the pump head minus the head loss across the valve.

**5.6.4.3 System Data.** Required systems data information includes

- (a) system layout
- (b) static head and if possible the system curve
- (c) operating hours. Through discussion with operating personnel, note approximate annual, seasonal, weekly, and daily operating hours, along with variations over time.
- (d) P&ID diagrams
- (e) pump control method
  - (1) VSD
  - (2) throttled (valve percentage open if available)

- (3) bypass/recirculation
- (4) on/off
- (5) more than one pump or split duty
- (6) not controlled (pumps just run)

**5.6.5 System Functional Baseline.** The assessment team shall record data associated with system function and production process information. An estimate of the long-term (annual, when possible) load profile shall be developed, and used as a baseline for future system performance comparison. The assessment should record system operating conditions in a way that can be accessed in the future. Comparisons of future performance will require adjustments for changing system function, including factors such as production shifts per day and amount and type of products being produced.

## 5.7 Data Collection Methodology

**5.7.1 System Information.** The system curve (or curves) is needed to assess most applications of pumping systems. The system curve can be calculated from two different operating points on the curve. These two points usually are the static head at zero flow and one operating point. In some rare cases it is impossible to assign a system curve.

The system curve shall be established and is essential for understanding the pumping system and the consequences to the system as a whole resulting from changes to any part of the system.

Demand variations as a function of time shall be established so that the appropriate measurements can be made.

**5.7.2 Measurement of Pump and Motor Operating Data.** As described above, the primary required data is head, flow, power, and operating time.

If the operating conditions of the pumping system are constant or only vary minimally in time, a snapshot of the operating conditions might be enough to assess the system. If the system demand varies over time, the assessment team shall determine if the system needs to be monitored over time and what time period is reasonable to get a representation of all operating conditions.

Operating data might also be readily available in the facility process control or database of historical operating conditions.

**5.7.3 Pressure.** Pressure measurements should be made using calibrated reliable gauges or transducers.

It is important to realize the calculation of efficiency varies based on the locations of the pressure measurements. If only the pump efficiency is wanted, pressure measurements should be made close to the pump on both the suction and the discharge side. Typically, this is not sufficient for an assessment. When measuring pump performance it is recommended that head losses between the suction and discharge head measurement points at the pump be estimated.

To assess the system efficiency, the measured pressures have to be relevant to the system demand.

**5.7.4 Flow.** The system flow rate shall be determined to establish pump and system efficiencies. Flow rates shall be measured whenever practical, and calculated using a proven methodology when measurement is not practical. Measurements are preferably made with calibrated flowmeters that are properly installed into the system and known to be accurate across the range of measured conditions. Ideally, there will be ten diameters of straight pipe upstream and five downstream of a flow meter. This ensures a fully developed flow profile and reduces measurement error. When necessary to use portable flow meters, verification of the measurements should be performed by reinstalling the flowmeter in an alternate location or using multiple measurement techniques. If large variations are found, the measurements shall be considered unreliable.

In some cases, it is necessary to determine the flow rate from the pressure drop across a component with known characteristics or by using data from the pump manufacturer's performance curve. In such cases, the data should be cross-correlated with both pressure and power measurements.

**5.7.5 Motor Input Power.** The motor input power (or VFD input if applicable) is used in calculating both pump and pumping system efficiency. Preferably, the input power should be measured directly using a power meter, which should give the most accurate results. When it is not possible to measure power directly, an acceptable alternative is to estimate or measure voltage and measure current delivered to the motor. If basic motor information as described in para. 5.6.1.1 is available and valid, motor output can be estimated. The calculation depends on estimates regarding the size of power factor. The accuracy of such estimates increases with the load of the motor and is reasonably accurate over 50% of the rated power of the motor. There are computer programs available that make these kinds of estimates.

Obtaining electrical measurements presents hazards to health and safety and therefore shall be performed only by a qualified electrical worker trained in the use of the measurement equipment per NFPA 70E, Standard for Electrical Safety in the Workplace.

## 5.8 Cross Validation

To accurately characterize the performance and opportunities for improving pumping systems, three basic types of measurements are required: flow rate, pressure, and power. In many industrial pumping applications, it is not feasible to acquire one or more of these parameters, or their acquisition may require considerable time and cost. In order to estimate potential savings opportunities, proxy data may be very helpful. Examples of proxy methods include

- (a) pump head and pump head curve to estimate flow rate
- (b) electric power and motor performance curve (or estimates) to estimate shaft power, and then use the shaft power and pump shaft power curve to estimate flow rate
- (c) measured valve position and flow rate combined with the valve characteristic curve to estimate differential pressure
- (d) measured drawdown and fill times, along with well or sump dimensional data, to estimate pump flow rate

Proxy methods can be used for preliminary quantification of potential energy savings opportunities and to help determine whether the magnitude of savings is sufficient to warrant further investigation.

It is beyond the scope of this Standard to detail the various cross-validation techniques, but they are vital tools in the assessment and solution-development process.

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

The final step in conducting the assessment is the presentation of findings and preliminary recommendations. This wrap-up meeting should be attended by the entire assessment team. During this meeting, outstanding questions and issues from the assessment team should be addressed. The tentative results of the assessment shall be formally presented and should include but not be limited to

- (a) review of the assessment process used
- (b) energy intensity or efficiency of the system(s) assessed
- (c) tentative recommended improvements, with preliminary energy and cost savings, if available
- (d) discussion of any further analysis recommended
- (e) any general comments and observations

The results presented shall be qualified as preliminary, subject to further analysis and refinement. Target dates for the delivery of a draft and final versions of the written report shall be set by mutual agreement.

## 6 ANALYSIS OF DATA FROM THE ASSESSMENT

### 6.1 Common Causes and Remedies for Excessive Energy Use

The collected data shall be analyzed to determine the optimal amount of energy required to perform necessary system functions. Software tools, when applicable, may be used to perform calculations. However, it is critical that a thorough understanding of system requirements be established before the application of any analysis technique. Experience has shown that failure to understand the actual process requirements can be the single largest contributor to inefficient system operation.

Therefore, it is necessary to distinguish between system design specifications and actual process requirements before attempting to quantify opportunities. At a fundamental level, opportunities to reduce pumping system energy consumption will comprise at least one of three actions. There is often overlap among the three actions such that one change can be attributed to more than one category. An example of this would be increasing the run time of a batch operation by decreasing the flow rate. Decreasing the flow rate, while not changing the system curve, will change where a pump is operating on the system curve, and in a highly frictional system this could significantly reduce the head required for system operation.

It should be understood that once a physical change is made to the system, the system curve will likely change, resulting in different system requirements and the need for another iteration of system analysis. Each time the system is modified there is the potential to redefine optimal operation for that system.

**6.1.1 Reduce System Head.** Examples of opportunities to reduce the system head are shown below. This list is not comprehensive. Rather, it shows some of the most common opportunities identified by experience.

- (a) Remove/reduce unnecessary throttling.
- (b) Clean or perform maintenance on fouled components such as heat exchangers.
- (c) Isolate flow paths to nonessential equipment or equipment that is not operating.
- (d) Maintain proper fill and venting of elevated sections of pipe.
- (e) Reduce/remove sediment and scale buildup.
- (f) Employ an air gap between pipe discharge and receiving tank when isolation is not necessary.
- (g) Eliminate operating with a flow rate that exceeds the system requirement.
- (h) Replace old or corroded pipe, using larger diameter pipe where feasible in high-velocity systems, and reduce the number of fittings as feasible.

**6.1.2 Reduce System Flow Rate.** Examples of opportunities to reduce the system flow rate are shown below. This list is not comprehensive. Rather, it shows some of the most common opportunities identified by experience.

- (a) Maintain appropriate differential temperatures. Pumping systems are often employed to circulate cooling water for various processes. Often, systems will operate with a higher flow rate than is necessary to remove heat from the system. For example, if a cooling tower is designed for a 10°F differential temperature and the flow rate is such that a 2°F differential temperature is maintained, there is a good chance the system flow rate can be reduced.
- (b) Isolate unnecessary flow paths.

- (c) Batch processes that are basically fill and drain can benefit from reducing the flow rate as long as it does not create an unacceptable change to the production schedule.
- (d) Turn off pumps when flow is not needed.

**6.1.3 Ensuring that Components Operate Close to Best Efficiency.** The operating efficiencies of the various components that comprise the pumping system can vary substantially depending on where they operate on their respective curves. As a rule, motors should not be operated below 30% of the rated load. Pumps should preferably be operated close to BEP. Operation away from BEP quickly reduces pump efficiency.

It should also be noted that different types of electric motors and steam turbines can differ substantially in efficiency. See para. 5.6.1.

**6.1.4 Change Pumping System Run Time.** Opportunities based on changing system run time are often used where the system requirement is dominated by static head. Such uses include, but are not limited to

- (a) sumps/lift stations.
- (b) systems with electric rates that change based on time of use or have a demand component.
- (c) systems that run when the process is not operating. Often a recirculation loop is employed rather than turning a pump off when flow is not needed.

## 6.2 Basic Energy Reduction Opportunity Calculations

The relationship between pump efficiency and pumping system efficiency is described in this paragraph.

"Pump efficiency" is the ratio of the hydraulic pump output powers of the pumped liquid to the mechanical pump (shaft) input power ( $P_p$ ), usually expressed as a percentage. The equation for calculating pump efficiency ( $\eta_p$ ) is as follows:

$$\eta_p = \frac{P_w}{P_p} \times 100$$

The pump output power,  $P_w$ , is calculated with the following equations:

$$\text{(U.S. Customary units, hp)} P_w = \frac{Q \times H \times s}{3,960}$$

$$\text{(SI units, kW)} P_w = \frac{Q \times H \times s}{367}$$

where

$H$  = total head, ft (m)

$Q$  = rate of flow, gal/min ( $\text{m}^3/\text{h}$ )

$s$  = specific gravity or relative density

There are two ways of characterizing energy reduction potential:

- (a) measure/estimate existing performance and compare it to optimal performance or
- (b) measure/estimate existing losses

There are various techniques and tools that may be used with these two fundamental methods. The specific

techniques may vary considerably in terms of ease of use, accuracy of results, and specificity of potential solutions.

## 7 REPORTING AND DOCUMENTATION

### 7.1 Final Assessment Report

At the conclusion of the onsite 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 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) annual energy use baseline
- (h) performance improvement opportunities and prioritization
- (i) recommendations for implementation activities
- (j) appendices

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

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

**7.2.2 Facility Information.** A detailed description of the facility, background, and facility purpose shall be included in this section.

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

**7.2.4 Description of System(s) Studied in Assessment and Significant System Issues.** The report shall include a detailed description of the specific system(s) on which the assessment was performed. Depending on the system assessed, the discussion of system operation can be extensive and should be supported by graphs, tables and system schematics. Supporting documentation should also be included to clarify the operation of the system components and their interrelationships.

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

### 7.2.5 Assessment Data Collection and Measurements.

The methods used to identify and interview key facility personnel, obtain data, and conduct measurements shall be identified, including an overview of the measurement plan. Measurement data and observations required for para. 7.3 not reported in para. 7.2.6 shall be placed in an appendix. For a Level 1 assessment, there should be less quantitative data since the focus is to prioritize potential energy savings opportunities. Relevant data shall include

- (a) defining system requirements and a determination of how system operation changes during the year (drawings, system process data).
- (b) pump total dynamic head (TDH), component frictional head losses and system curve should be developed where appropriate and possible (use of existing gauges, portable pressure transducers or based on suction/discharge tank elevations).
- (c) electrical energy use data (use of portable or existing instrumentation).
- (d) determination of pump operating hours and flow intervals (plant historical data, staff input, data loggers).
- (e) pump performance information, when available (generic or shop test pump curves, field data).
- (f) measurement or estimation of system losses (e.g., losses in valves and heat exchangers).

This section should also include a discussion of data accuracy and the need for verification before the recommended projects are approved.

A Level 2 assessment will require less quantitative data reporting than a Level 3 assessment.

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

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

**7.2.7 Annual Energy Use Baseline.** If sufficient data exist, the assessment report shall contain the baseline of total annual energy use for the pumping system. The analytic method used to develop the annual energy use baseline shall be described. Facility functional and production process observations and information shall be reported.

The report shall clearly describe the assessment baseline as a basis for both routine and non-routine adjustments. Adjustments are calculated from identifiable physical facts with respect to changes in the physical plant and production process. The report shall provide sufficient information on the facility functional baseline during the assessment to provide a basis for adjustments.

Routine adjustments are those energy-governing factors that are expected to change such as production volume variations. Baseline relationships of production-dependent and time-dependent system energy consumption should be clearly stated.

Nonroutine adjustments are related to factors that are not usually expected to change during the short term. Factors such as facility size and the design, type, and number of production lines involving pumping systems are examples of non-routine adjustments.

**7.2.8 Performance Improvement Opportunities Identification and Prioritization.** The analysis shall quantify estimates of energy reduction and energy cost savings from recommended performance improvement opportunities. Additional calculations may address other energy and non-energy benefits. The report shall identify the methods of calculation and software models used with assumptions clearly stated.

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

Details on performance improvement opportunities to be documented and reported shall include a sufficiently detailed description of the actions required for project implementation. To aid in the selection of projects for implementation, the assessment team should categorize the opportunities 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)

In the analysis section of the report, the pumping system energy-use baseline shall be established and energy

savings opportunities developed. This is typically done by taking instantaneous flow, pressure and electrical measurements and determining operating hours at varying system conditions.

For all assessment levels, the analysis for baseline development and proposed recommendations should be performed in sufficient detail to allow facility staff to understand all parts of the analysis. If software is used, the data entered into the software shall be clearly defined. The supporting analysis data may include spreadsheets, diagrams, software output screen captures, and calculations. The steps, assumptions and calculations of the analysis should be presented in a logical detailed format that can be understood by other engineering professionals for third-party verification if required.

This part of the assessment may also address other energy and non-energy benefits such as improving resource utilization, reducing per-unit production cost, reducing life-cycle costs, and improving environmental performance. These benefits can be mutually agreed upon with facility management and can be a range.

The amount of detail included in the energy efficiency recommendations shall vary considerably for each assessment level. Recommendations are typically classified as Operation & Maintenance Recommendations (OMs) or as Energy Conservation Measures (ECMs). The recommendations reviewed in this report section shall be prioritized in order based on facility staff acceptance and cost effectiveness. Each subsequent measure should include the interactive savings effect of the previously recommended measure. Consideration must also be given to projects that may be easily implemented versus improvements that may not be easily pursued until plant production lines are out of service.

The presentation of each measure should be limited to a brief description of the proposed improvement and a summary of the benefits. If needed, it is also appropriate to recommend a higher level assessment before the measure is pursued.

General observations of nonpumping system-related energy saving opportunities should also be discussed.

### **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 as needed, 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 and payback period.



The assessment report should note that further engineering analysis be performed prior to implementing the recommendations contained in the assessment report.

**7.2.10 Appendices.** Material that is lengthy and not required for the presentation of the report should be included in appendices to ensure clarity of the body of the report. Detailed supporting data, such as energy use calculations, cost savings calculations, and economic analysis, should be referenced and included in the report 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 analyses performed in section 5 can be confirmed by a third party. This documentation shall be structured so it can be easily accessed by verifiers and other persons not involved in its development.

### **7.4 Review of Final Report by Assessment Team Members**

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

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## NONMANDATORY APPENDIX A KEY REFERENCES

ANSI/Hydraulic Institute Pump Standards: 28 various standards covering rotodynamic and positive displacement pumps. Available at [www.pumps.org](http://www.pumps.org).

*Improving Pumping System Performance: A Sourcebook for Industry*. 2006. U.S. Department of Energy. Available at <http://www1.eere.energy.gov/industry/bestpractices/pdfs/pump.pdf>.

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*Pump Systems Basic Assessment Guide*. 2007. BC-Hydro and Pump Systems Matter. [www.pumpsystemsmatter.org/BasicAssessmentGuide](http://www.pumpsystemsmatter.org/BasicAssessmentGuide).

*Pumping System Assessment Level Guide — An Overview*. 2006 Casada, Cox, Angle and Milan.

*Pumping System Assessment Tool Training Materials*. 2008. U.S. Department of Energy.

*Pumping System Optimization: Opportunities to Improve Life Cycle Performance Course*. 2009. Pump Systems Matter and Hydraulic Institute. [www.PumpSystemsMatter.org](http://www.PumpSystemsMatter.org).

*System Efficiency: A Guide for Energy Efficient Rotodynamic Pumping Systems*. 2006. Europump. [www.europump.org](http://www.europump.org).

*Variable Speed Pumping: A Guide to Successful Applications*. 2004. Hydraulic Institute and Europump. [www.pumps.org](http://www.pumps.org) and [www.europump.org](http://www.europump.org).

## NONMANDATORY APPENDIX B PRESCREENING WORKSHEET

A = High Priority		B = Med Priority		Blank = No Action		Priority	
Equipment Information		System name/description [Note (1)]					
		Pump Type [MC, PD, Vacuum, Centrifugal] [Note (1)]					
		Certified Pump Performance Curve [Note (1)]					
		Pump ID/process area [Note (1)]					
		Motor nameplate data [Note (1)]					
		Service (e.g., utility, process, etc.)					
		Time in service (years)					
		Indicate shared duty pump systems / in-service spares					
		Voltage					
Control Schemes (check all that apply) [Note (1)]		Adjustable speed drive					
		Throttled (% open if available)					
		Bypass/recirculation					
		On/off					
		More than one pump/split duty					
Operating Parameters (provide if readily available, otherwise indicate with check if it is acquirable)		Not controlled (pumps just run)					
		Operating hours or % of time equipment operates [Note (1)]					
		Power or current					
		Flow requirements have changed or are expected to change					
		Design flow rate					
		Operational flow rate					
		Design head					
		Operational head					
Other Symptoms		Upstream pressure					
		Downstream pressure (after control valve, or bypass line, etc.)					
Additional Information (is acquirable?)		Cavitation at pump or in system?					
		System maintenance level (Hi/Med/Lo)					
		Typical flow rates and variation thereof					
		Duration diagrams					
		Maintenance costs					
		PID/DCS screen-shots					

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**NOTE:**

(1) Priority data entries.

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