ASME EA-4–2010

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Energy Assessment for Compressed Air Systems

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Date of Issuance: April 23, 2010

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.

The American Society of Mechanical Engineers
Three Park Avenue, New York, NY 10016-5990

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FOREWORD

This document provides a standardized framework for conducting an energy assessment for compressed air systems, hereafter referenced as an "assessment." A compressed air system is defined as a group of subsystems comprised of integrated sets of components used to deliver compressed air energy to manufacturing equipment and processes. 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 lifecycle costs, and improving environmental performance related to the assessed system(s).

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

This 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 does not need to 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.

This Standard is part of a portfolio of documents and other efforts designed to improve the energy 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 the understanding of the assessment standard. The guidance documents provide rationale for the technical requirements of the assessment standard and give technical guidance, application notes, alternative 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 manage energy supply, demand, reliability, purchase, storage, use, and disposal and is used to control and reduce an organization's energy costs and energy-related environmental impact. NOTE: This ANSI standard will eventually be superseded by ISO 50001, now under development.

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

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

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

ASME EA-4–2010 was approved by the EA Industrial System Energy Assessment Standards Committee on January 7, 2010 and approved by the American National Standards Institute (ANSI) on March 3, 2010.

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

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

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

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

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

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

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

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ENERGY ASSESSMENT FOR COMPRESSED AIR SYSTEMS

1 SCOPE AND INTRODUCTION

1.1 Scope

This Standard covers compressed air systems, which are defined as a group of subsystems comprised of integrated sets of components, including air compressors, treatment equipment, controls, piping, pneumatic tools, pneumatically powered machinery, and process applications utilizing compressed air. The objective is consistent, reliable, and efficient delivery of energy to manufacturing equipment and processes.

The compressed air system can be considered as three functional subsystems.

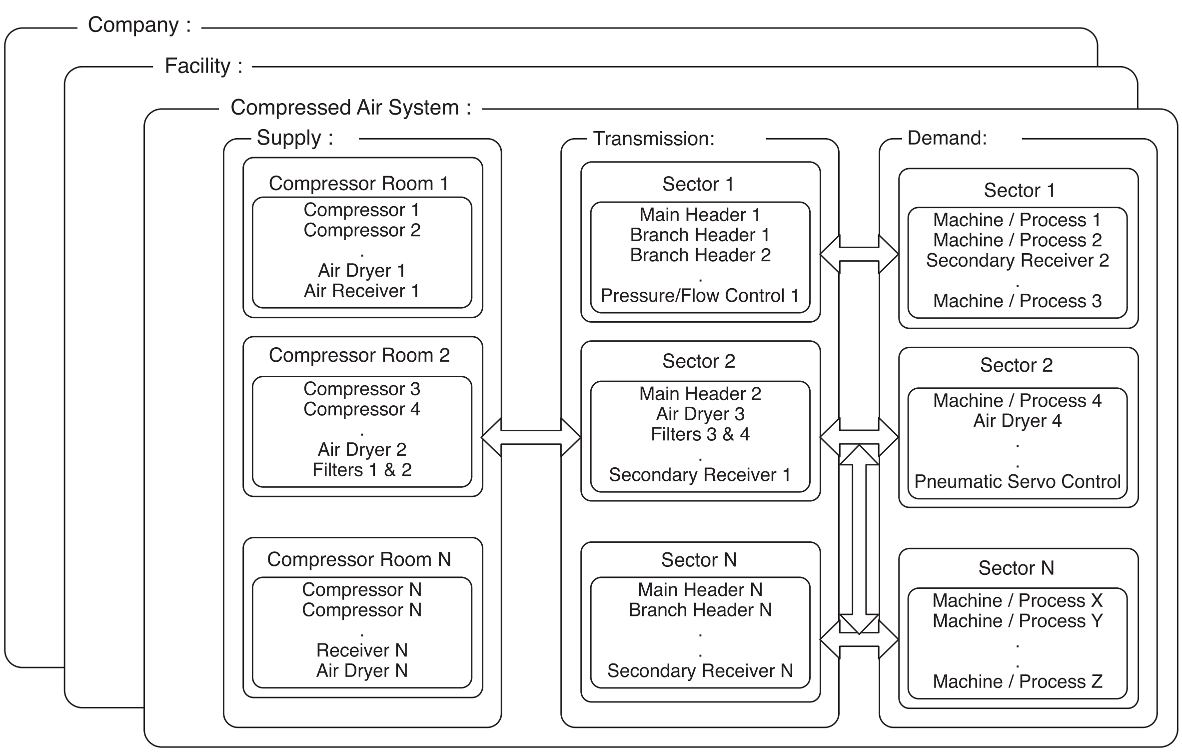
supply: conversion of primary energy resource to compressed air energy. The supply subsystem includes generation, treatment, primary storage, piping, controls, performance measurement equipment, and reporting systems.

transmission: movement of compressed air energy from where it is generated to where it is used. The transmission subsystem includes distribution piping mainline and branch headers, piping drops, secondary storage, treatment, transmission controls, performance measurement equipment, and reporting systems.

demand: the total of all compressed air consumers, including productive end use applications and various forms of compressed air waste. The demand subsystem includes all end uses, point-of-use piping, secondary storage, treatment, point-of-use controls, performance measurement equipment, and reporting systems.

This Standard sets requirements for conducting and reporting the results of a compressed air 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 does not need to 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

Fig. 1 Compressed Air System Hierarchy



improving the overall energy performance of the system. This Standard is designed to be applied primarily at industrial facilities, but many of the concepts can be used in other facilities, such as those in the institutional and commercial sectors.

Assessments involve collecting and analyzing 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 lifecycle costs, and improving environmental performance related to the assessed system(s). Assessment activities 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 operation and performance data; document the assessment process; show results, recommendations, and energy savings projections; and improve facility personnel's understanding of system energy use and operation.

This Standard sets requirements for

(a) organizing and conducting a compressed air 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 an assessment for compressed air systems but sets the requirements that need to be met during the assessment. For additional assistance, see the companion ASME Guidance for ASME EA-4 Energy Assessment for Compressed Air Systems on how to apply this Standard.

(a) This Standard does not specify how to design a compressed air 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

1.3 Introduction — Using the System Assessment Standard

Industrial facilities use compressed air as an essential energy source to power tools or machines and for process applications. Characteristics of compressed air, such as responsiveness and safety, make it an effective and desirable means of delivering energy to production.

There are many end uses of compressed air energy applied to all types of different industries. No two compressed air systems or compressed air system assessments are identical. Therefore, this Standard is provided as a flexible framework that, when applied to the wide variety of industrial compressed air systems, can accomplish an effective energy and performance assessment.

The system assessment framework is presented as a matrix of assessment objectives, action items, and methodologies. The matrix approach is intended to facilitate selection of activities to be performed in the assessment. Two matrices, "Preliminary Data Collection" and "Plan of Action," are presented in Mandatory Appendices I and II. Each matrix includes required elements and supplemental elements of assessment activity. Required elements primarily focus on energy reduction benefits and apply to virtually all compressed air systems. Supplemental elements described in each matrix do not apply to every system or have primarily nonenergy related performance benefits.

Ultimately, use of this Standard is at the discretion of those participating in the assessment. The assessment team (see para. 4.1), working with production process information and compressed air system knowledge, shall establish the plan of action and statement of work (SOW) for the assessment.

Plants that desire full conformance with this Standard shall complete all required elements of activity. Required elements, assessment objective, action item, and methodology are shown in Mandatory Appendices I and II using black text with white background. Each required element, assessment objective, and action item shall be investigated using one or more methodologies also shown in black and white text.

Users who desire full conformance with this Standard may decide that in addition to required elements, their technical and business objectives will benefit by including some supplemental assessment activities. Based on the assessment team's expertise and judgment, supplemental assessment activities may be included in the assessment plan of action and SOW. Once a supplemental element is included in the assessment SOW, it is a required element, and the applicable requirements of the Standard shall apply. In Mandatory Appendices I and II and in para. 4.7, these supplemental elements are presented with a shaded background as shown below.

NOTE: Shaded items are supplemental elements for an assessment.

Users who do not desire full conformance with this Standard may view all elements of assessment activity equally without regard to required elements. The assessment framework is provided to give the user maximum flexibility to manage the assessment process as it best supports their individual technical and business objectives.

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.

Energy conservation incentive programs may use the assessment framework to communicate with applicants the scope of assessment activity required to participate in a program.

1.3.1 The System Assessment Process. The assessment should document issues and concerns about present compressed air use, critical production functions, and poor performance. The assessment should identify and quantify energy waste, compressed air supply and demand balance, energy use, and total compressed air demand. These generalizations should be used to guide selection of objectives and action items for preliminary data collection (para. 4.6).

1.3.2 System Energy Efficiency. Most industrial facilities are both producers and consumers of compressed air, as shown in Fig. 2. An industrial plant's efficient use of compressed air energy is based on the total energy input to the compressed air system and the production output of the manufacturing process. There are two basic ways to reduce the energy consumption of a compressed air system: produce compressed air more efficiently; and consume less compressed air.

For a given level of production output, the compressed air system assessment requires two important measures

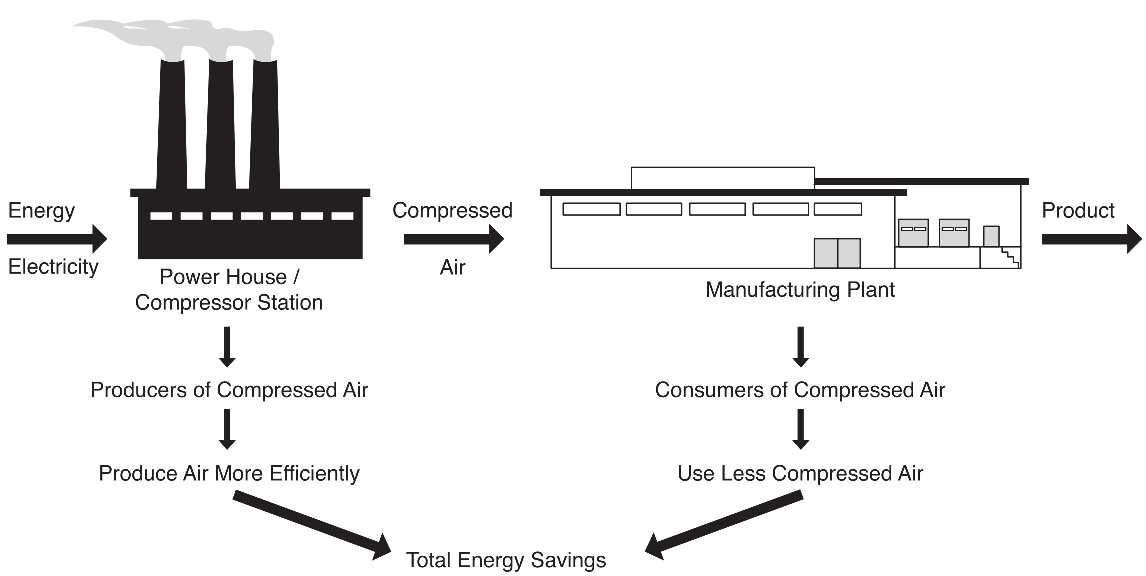
(a) the total amount of primary energy resource used to generate the total amount of compressed air consumed

(b) the total amount of compressed air consumed for a given level of production output

Paragraph 1.3.2.2(a) is a measurement of supply, and para. 1.3.2.2(b) is a measurement of demand. If supply is considered without demand or demand is considered without supply, the analysis is incomplete. Application of this Standard shall apply the systems approach (para. 1.3.3) considering both supply and demand and the relation each have to the other.

1.3.2.1 Compressed Air Energy Conversion. Compressed air is an inefficient means of energy transmission. Beginning with 15% conversion efficiency and considering other inefficiencies, such as frictional resistance in transmission, waste, and misuse, 10% or less of the primary energy resource is applied to productive work.

Fig. 2 Industrial Facility — Producer and Consumer of Compressed Air



1.3.2.2 Energy Reduction Opportunities. A measurement of compressed air supply efficiency is the relationship between the total net amount of compressed air delivered and the total amount of primary energy consumed.

(a) Compressed air supply efficiency energy reduction opportunities include

(1) improve compressor efficiency, thermodynamic, volumetric, or mechanical

(2) reduce compressor discharge pressure

(3) improve control strategy, for both individual and multiple compressor control

(4) reduce parasitic losses, friction loss in piping and filtration, air loss to leakage, energy input to air dryers, and purge air loss for some types of air dryers

(b) For a typical production day, total air demand is a measurement of the total amount of compressed air consumed. Compressed air demand energy reduction opportunities include

(1) reduce compressed air leakage

(2) reduce system operating pressure to eliminate artificial demand

(3) eliminate compressed air use and replace with a more efficient energy resource

The compressed air system's greatest energy reduction opportunity is associated with the amount of avoided energy input to the system that results from reducing compressed air demand.

1.3.2.3 Sustainable Energy Savings. Given that many stakeholders' highest priority is a reliable compressed air system that supports manufacturing equipment and processes, energy savings that represent risk to the production process are not sustainable. Simply put, if the system experiences an event that causes a production curtailment or outage, the energy efficient operating scenario will be quickly abandoned in favor of the (former) less efficient but more reliable operating methodology.

Energy savings opportunities should be combined with a comprehensive group of remedial measures to create a robust and reliable compressed air system. For example, reducing system operating pressure is an effective energy savings opportunity. However, if it is implemented without remedial measures to reduce irrecoverable pressure loss, provide necessary compressed air storage, and appropriate automation of air compressors to reliably support end-use applications at the lower operating pressure, system pressure will ultimately be returned to the higher operating pressure.

Addressing only the energy component and the way in which it is measured, analyzed, reported, implemented, and verified without assessing what is needed to ensure reliability is a classic scenario for failure in achieving sustainable energy savings.

1.3.3 Systems Approach. The basis of this Standard uses systems engineering methods applied to a compressed air system assessment. Systems engineering focuses on defining stakeholders' needs and required system functionality early in the development cycle, documenting system requirements, and then proceeding with system design while considering the entire system.

Application of a systems approach to a compressed air system assessment directs the focus toward total system performance rather than individual component efficiency. It is necessary to

(a) understand compressed air point of use as it supports critical plant production functions

(b) correct existing poor performing applications and those that upset system operation

(c) eliminate wasteful practices, leaks, artificial demand, and inappropriate use

(d) create and maintain an energy balance between supply and demand

(e) optimize compressed air energy storage and air compressor control

1.3.4 Systems Engineering Process. Compressed air systems engineering is an iterative process including the requirements definition, the assessment process, and evaluation of outcomes and results. It is a fluid process whereby outcomes and results may achieve defined goals or may result in a new or revised requirements definition.

For this Standard, the systems engineering process is described in ten steps.

(a) Identify what you want to accomplish.

(b) Identify what you need to evaluate.

(c) Get organized, identify the assessment team, and get plant background information.

(d) Define the present system.

(e) State site-specific system assessment goals.

(f) Design the system assessment (what, how, when).

(g) Test the assessment's design for relevance, completeness, and cost effectiveness.

(h) Do the assessment, and gather facts and data.

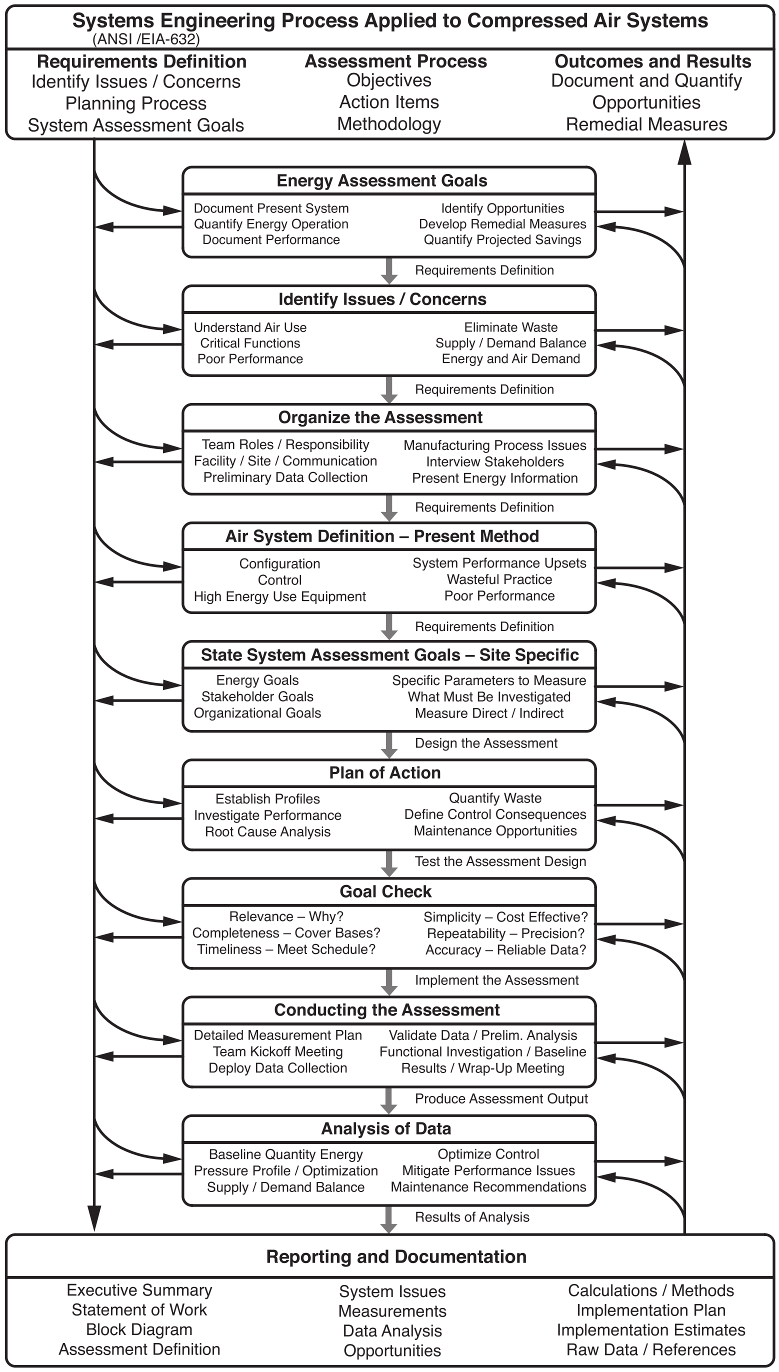
(i) Analyze the facts and data to develop solutions and estimate cost and savings.

(j) Report and document recommendations and findings.

There are many compressed air system integration factors where decisions related to one component or subsystem impact other components or subsystems. Concept alternatives should be proposed and analyzed before final conclusions are reached.

The chart shown in Fig. 3 illustrates the systems engineering process as applied to an assessment. It is derived from the systems engineering process overview chart presented in ANSI/GEIA Standard ANSI/EIA-632, "Process for Engineering a System."

Fig. 3 Systems Engineering Process Overview



2 DEFINITIONS

action item: a tactic used to acquire system knowledge consistent with assessment objectives.

assessment: activities undertaken to identify energy performance improvement opportunities in a compressed air system that 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 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 goal: investigation of system operation and identification of energy efficiency opportunities for system optimization.

assessment objective: collection of tactical activities (action items) undertaken to attain the assessment goal.

capacitance: in compressed air systems, capability of a storage volume, primary receiver, dedicated use point receiver, or other device for storing compressed air energy. Capacitance is expressed as the ratio of stored air volume (scf) to the storage pressure differential (psi).

characteristic signature: dynamic profile of airflow rate and pressure changes with time that occurs during particular production operations and compressed air demand events.

compressed air system: a functional group of subsystems comprised of integrated sets of components, including air compressors, treatment equipment, controls, piping, pneumatic tools, pneumatically powered machinery, and process applications utilizing compressed air.

control signal pressure: air pressure that is applied to the pressure switch, transducer, pilot valve, or other control device that creates an input signal to a compressor capacity control system.

coverage interval: the interval (plus/minus percentage or minimum to maximum value) that, based on the information available, contains the true value of a parameter. The expression of coverage interval is associated with a specified confidence level.

data logging: measurement of physical parameters while tabulating a periodic log (record) of their numerical value using time-aligned data frames for the plurality of recorded parameters.

dynamics: data logging while creating a sufficiently high frequency periodic log (record) so as to investigate the time-based variation of measured physical parameters.

trending: data logging during an extended duration of time for the purpose of investigating commonality in the measured physical parameters throughout time.

direct measurement: a method to determine the value of a measured parameter that is done with an instrument designed for such a task.

drawdown: the circumstance observed in a compressed air system that is characterized by continual pressure decay arising from a compressed air system event whereby air demand exceeds the total generation capacity of supply.

drawdown pressure: the total amount of pressure decay in compressed air system pressure (psi) that occurs during a particular drawdown event.

drawdown rate: the rate of pressure decay per unit of time (e.g., psi/min) that occurs during drawdown of a compressed air system.

NOTE: Drawdown rate is nonlinear; pressure decays more rapidly at higher system pressure. In most cases, the nonlinearity of drawdown rate is ignored.

dynamics: the study of the effect of time variant parameters on system performance.

end-to-end (*measurement end-to-end*)*:* in measurement, includes the entire measurement system from the transducer for the parameter to be measured to the record of the resultant value.

equipment connection point: in compressed air piping, is at the inlet of the first control component associated with the point of use. That component may be a shut-off service or lock-out valve, a filter/ regulator /lubricator combination, a solenoid control valve, or other control component.

feasibility estimate (*screening estimate*)*:* a statement of implementation cost that considers very little work has been done to define the project's scope. Defined as an ASTM Class 5 estimate, which considers <2% completion of the project definition; by ASTM International E 2516-06, 2006 "Standard Classification for Cost Estimate Classification System."

flow dynamic: situational operation of compressed air demands wherein the peak airflow rate and minimum pressure must occur simultaneously.

flow static: situational operation of compressed air demands characterized when peak airflow rate and minimum pressure required do not occur simultaneously.

indirect measurement: a method to determine the value of a measured parameter that is done through the measurement of a sufficiently comprehensive group of related parameters so as to quantify the desired parameter.

NOTES:

(1) Methods may include stipulated values and assumptions that allow the desired parameter to be determined from indirect measurements.
(2) Statement of the inferred value should include a description of the means used to arrive at assumptions and stipulated values, along with the process used for in-situ validation of assumptions and stipulated values.

inferred value: the result obtained by making an indirect measurement.

irrecoverable pressure loss: a reduction in compressed air pressure resulting from the interaction of airflow through the fixed resistance associated with a component of the air system (see also *recoverable pressure differential*).

minimum system pressure: the lowest possible air pressure a system can reach before adversely affecting the manufacturing process.

observe: a careful, methodical, deliberate act of an observer to examine a subject using cognitive analysis, empirical factual knowledge, and sensory processes.

operating period: a group of typical time periods that has similar compressed air energy and compressed air demand profiles (see also *typical operating period*).

point of use: in a compressed air system, where compressed air energy is converted to mechanical work or accomplishes a production-related task.

precision (*measurement precision*)*:* closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects.

pressure gradient: the rate of pressure change with respect to distance in the direction of maximum change. In fluid mechanics, the change in pressure P, along the length and distance X of a fluid conduit. It is represented by dP/dX.

NOTES:

(1) The air velocity in a pipeline depends on the magnitude of the gradient and resistance of the pipeline.
(2) Without gradient, there is no airflow. In a compressed air system, air moves from high-pressure toward low-pressure areas.

primary storage: compressed air storage system that is located on the generation side (supply) of a compressed air system. Primary storage maintains and controls a stored potential of useable compressed air energy on the generation side (supply) of a compressed air system. Primary storage is necessarily comprised of a storage volume (air receiver) and storage pressure differential (storage pressure – target system pressure), with appropriate control considerations (pressure/flow control).

recoverable pressure differential: compressed air pressure difference between the inlet and outlet of a control valve, which represents a variable resistance to airflow. The available compressed air energy represented by the upstream volume and greater pressure is recoverable to the system by opening the valve (see also *irrecoverable pressure loss*).

repeatable (*measurement repeatability*)*:* closeness of agreement in measured values using the same measurement procedure, operators, measuring system, operating conditions, and location, measuring the same parameters over a short period of time.

reproducible (measurement reproducibility): closeness of agreement in measured values using different measurement procedures, operators, measurement systems, and locations, measuring the same parameters at a different time.

root cause analysis: the process by which a single event that represents a fault in work products and processes is analyzed to determine the fundamental cause for the fault. Based on this understanding, a correction can be made to the product or process to resolve the fault (Source*:* INCOSE Systems Engineering Measurement Primer).

sample rate (scan rate): indicates how fast a digital data acquisition system is making measurements of each individual input channel. Sample rate is expressed in terms of number of samples/unit of time (e.g., 10 samples/min or 1 sample every 6 sec; higher speed sample rates may be expressed in Hz or kHz, e.g., 10-Hz sample rate).

sector: a sector is a functional portion of a compressed air system that is a subset of the total system. Sectors may be segregated from the total system for purposes of delivered air quality, target pressure, priority, or other unique functional requirements.

spot check measurement: measurement of physical parameters creating a log (record) of their numerical value that is carried out at random time intervals or limited to a few instances.

stipulated value: the value of a parameter based on assumption, reference to literature, calculation, etc.

NOTE: A process for in-situ validation should confirm that the stipulated value fairly represents the probable true value of the parameter.

storage pressure differential: the difference between pressure in a storage volume and the desired target pressure of the connected system or sector.

storage volume: the volume contained within a storage vessel (an air receiver tank) usually expressed in cubic feet or gallons (volume).

target pressure: compressed air pressure that is desired to be consistently supplied to a compressed air system or sector of a compressed air system. It should be selected as the lowest possible pressure that allows for reliable operation of manufacturing processes. Typically target pressure is slightly greater than minimum system pressure (see also *minimum system pressure*).

transmission system: begins at the system supply point(s) with distribution piping, ending at piping drops to point-of-use connections. The transmission system may include demand side treatment equipment, secondary storage, pressure/flow controllers, and other measurement or control components.

Type B: estimate of uncertainty (see *uncertainty, Type B*).

typical operating period: a time period that represents a period of typical plant operation, such as a peak-season weekday or an off-season weekend day. Depending on production activity, the plant may have several different typical periods of operation (see also *operating period*).

uncertainty (quantification of uncertainty): the quantification of doubt about the result of measurement.

Type A: uncertainty estimate is the result of rigorous statistical evaluation of repeated results of the same measurement.

Type B: uncertainty estimate is the result of informed judgment, experience, knowledge of the measurement instrument, and measurement process, along with reference data taken from handbooks or other authoritative sources.

usable air storage: the volume of compressed air (normally expressed in standard cubic feet, scf) that can be delivered from an air storage system without dropping below a specified minimum system pressure.

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 B lists key references with additional information on compressed air systems, measurement, and systems engineering.

4 ORGANIZING THE ASSESSMENT

4.1 Identification of Assessment Team Members

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

4.1.1 Required Functions and Personnel

4.1.1.1 Resource Allocation

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

(b) Exercise final decision making authority on resources.

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

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 Compressed Air 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 compressed air systems.

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

Information on other assessment team members is identified in para. 4.8.1.

4.2 Facility Management Support

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

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

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

4.3 Communications

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

4.4 Access to Equipment, Resources, and Information

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

(a) plant areas and compressed air system components required to conduct the assessment

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

(c) other information sources such as drawings, manuals, test reports, historical utility bill information, computer monitoring and control data, electrical equipment panels, and calibration records necessary to conduct the assessment

4.5 Assessment Goals and Scope

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

4.6 Initial Data Collection and Evaluation

The assessment team shall use Mandatory Appendix I, Preliminary Data Collection Matrix, for elements of assessment activity required to evaluate stakeholders' needs and system assessment requirements. The assessment team should define assessment requirements using objectives and action items including, but not limited to, initial data collection; measurement of key system operating variables; facility specialist interviews; review of previous assessments, audits, baselines, or benchmarking; identification of already-approved/initiated system projects; review of utility bills and energy costs; and preliminary data evaluation.

The preliminary data collection elements are described in Mandatory Appendix I. The matrix presents assessment objectives, action items, and methodologies. Some are required elements of an assessment that is fully compliant with this Standard. Supplemental objectives, action items, and methodologies can be included at the discretion of the assessment team.

Required elements, assessment objective, action item, and methodology are shown in Mandatory Appendix I using black text with white background. Each required element, assessment objective, and action item shall be investigated using one or more methodologies also shown in black and white text. Supplemental elements of the assessment are written in black text with shaded background as shown here.

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).

See Mandatory Appendix I, I-2, c.1 through c.5, facility specialist interviews.

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 compressed air systems.

See Mandatory Appendix I, I-2, e.2 and e.4 through e.6, energy awareness and organizational energy management objectives.

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 purchased cost, demand charges, peak rates, time-of-the-day rate, and any other costs up to the point of use. Where necessary, appropriate costs should be assigned to onsite 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.

From this information, an average annual energy cost/kWh (electric) over the previous 12 mo shall be determined. A facility may have already established a marginal cost for energy that can be used.

See Mandatory Appendix I, I-2, d.2 and d.4, energy information.

4.7 Site-Specific Assessment Goals

Compressed air systems, the industries they serve, and end-use applications are very diverse. As a result, the goals of a compressed air system assessment vary from system to system. The assessment team shall determine assessment goals and develop the SOW for the assessment.

The assessment team shall develop the assessment goals as they apply to the plant site. These goals should be consistent with the organizational goals identified in para. 4.5, together with information about the present compressed air system and stakeholder needs (para. 4.6 and Mandatory Appendix I).

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

Using the plan of action matrix presented in Mandatory Appendix II, Plan of Action Matrix, the assessment team shall select assessment objectives, action items, and methodologies to develop a plan of action for the assessment.

This Standard specifies the requirements that shall be undertaken to conduct an assessment. These requirements are presented with black text on white background as shown in the following paragraph.

Required elements, assessment objective, action item, and methodology are shown in Mandatory Appendix II using black text on a white background as shown here. Each required element, assessment objective, and action item shall be investigated using one or more methodology also shown as black text on white background.

Supplemental elements of assessment are shown as illustrated here in black text with shaded background. Supplemental elements are provided to give the user a complete flexible framework for compressed air system assessment.

This Standard is structured to allow maximum flexibility in creating the assessment's plan of action meeting the needs of individual plant sites. The plan of action matrix shall be used as a framework to develop an effective assessment plan appropriate to a plant's unique compressed air system and site-specific assessment goals.

It is unlikely that any system assessment would include all of the supplemental (shaded) elements listed in Mandatory Appendices I and II. However, meeting the plant site goals and information needs may include other objectives and action items that are not listed here. Where the Standard is silent or inconsistent for any specific application, the assessment team shall adhere to the principles of systems engineering, apply the systems approach, and be sufficiently comprehensive to meet the intent of the Standard.

When developing the plan of action, consider that a required goal is to quantify the system's baseline energy use and compressed air demand. Baseline data will establish base-year energy data (Mandatory Appendix II, II-1, a.2). In addition to base-year energy data, documentation of base-year plant function and production process information (Mandatory Appendix I, I-2, b.1 through 4) is necessary. The baseline established by the system assessment will be used now and again in the future.

Preparation and documentation of the plan of action are central to the assessment. In addition to its immediate use, the plan of action forms a basis for future system performance evaluation. Consider that with implementation of system improvements, several years may pass before the original assessment plan of action is again reviewed. Therefore, the assessment team shall

(a) Describe the assessment plan of action in a manner that can be accurately interpreted by persons not involved in its development.

(b) Describe which aspects of system performance will receive detailed investigation, along with the nature of that investigation.

(c) Fully and clearly identify objectives, action items, and methodology planned for the system assessment.

(d) Clearly define measurements that will be made and their duration.

The assessment team using information and knowledge gained with respect to organizational, energy, and system performance goals, together with system requirements and stakeholders' needs, shall incorporate the plan of action into a SOW for the assessment.

Once the assessment team designates supplemental element(s) of assessment in the site-specific SOW, the conditions of the designated supplemental element(s) shall become a requirement of the assessment.

4.8.1 Identification of Other Assessment Team Members Required. The assessment considers the entire system from energy inputs to the work performed as a result of those inputs. As a result of facility specialists interviews, certain manufacturing equipment or processes that use compressed air may be identified for detailed study requiring the participation of individuals with specialized knowledge related to these applications.

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 shall 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

Conducting the assessment is the implementation phase of the plan of action in accordance with the assessment SOW and shall include the creation of final detailed plans for investigation and measurement of system performance and finalize necessary logistics. Assessment team members should be allowed authority and responsibility to plan, schedule, and implement specific assessment objectives and action items.

The assessment shall conclude with a wrap-up meeting allowing assessment team members to communicate findings and share information and data collected. The wrap-up meeting can also define requirements for additional assessment activity, summarize areas of greatest opportunity, and identify priorities for analysis of data.

5.1 Measurement Plan

The assessment team shall establish a detailed plan to schedule and implement the necessary measurements in accordance with site-specific assessment goals, the assessment action items, and SOW. For each action item, plan measurements as defined in the plan of action according to the specified methodology (spot check, data logging, trending, and dynamics) shall be developed.

The assessment team is responsible for maintaining quality assurance in the design and execution of the measurement plan as a consistent, repeatable, and reproducible process. The assessment team shall provide a Type B estimate of quantification uncertainty in terms of coverage interval and confidence. The target should be ±10% coverage interval with 90% confidence. Type B[1] estimates quantify uncertainty using informed judgment, experience, and general knowledge of the measurement system and instruments used, along with reference data taken from handbooks.

Best practice associated with measurement techniques, instruments, and digital data acquisition equipment is continually evolving. The measurement plan should reflect the present state-of-the-art within the constraint of providing cost-effective measurement (see para. 4.9).

The measurement plan shall adhere to principles of accuracy, transparency, and reliability.

5.1.1 Measurement Instruments. Measurement instruments and transducers shall be applied to directly measure parameters at conditions within the manufacturer's specified operating limits of the instrument. Instrument data sheets that describe the transducers-sensing element, relevant operating characteristics, and operating environment design limits should be available. The instrument manufacturer's accuracy or precision statements should be in accordance with the relevant industry standard for their product.

The most recent calibration information for instruments used should be reported.

The assessment team shall determine appropriate requirements for instruments used. If it is elected to perform calibration, the cost should be considered to ensure that the assessment remains cost effective (see para. 4.9).

5.1.2 Measurement Techniques. Measurement techniques will vary with individual assessment objectives and methodology that is required. Measurement techniques affect the end-to-end accuracy of the measurement system and resultant uncertainty of the measured values. The measurement plan should consider cost, the time available to gather the necessary data, and factors that affect end-to-end accuracy. A partial list of factors to consider is shown below.

(a) selection of the baseline period and duration of baseline measurement

(b) direct versus indirect measurement

(c) transducer installation

(d) electrical signal integrity

(e) sample rate and data interval

5.1.3 Baseline Period and Duration of Data Logging. The baseline period should include "typical operation" of plant functions. Typical periods are representative of the plant's planned or unplanned changes in production. Changes may be seasonal, based on the day of the week, market conditions, availability of raw materials, or other factors. Compressed air system energy profiles exhibit both time- and production-dependent variation. Depending on a particular period's production operation, the production-dependent portion of the plant's compressed air energy baseline will exhibit different characteristics. Time periods with similar compressed air energy profiles ("typical periods") are grouped together as different "operating periods."

When considering the duration of baseline measurement, the assessment team shall measure all typical periods of operation. Some typical periods, such as holidays, may represent a small fraction of the plant's compressed air energy base-year operation. Baseline performance for a typical period may be stipulated based on historical operating information. Stipulated baseline performance should not exceed 10% of the plant's base-year energy use.

5.1.4 Direct Versus Indirect Measurement. Direct measurement of a parameter is accomplished with an instrument designed for such a task.

Indirect measurement of a parameter is inferred through the measurement of a sufficiently comprehensive group of associated parameters so as to quantify the desired parameter. The assessment shall specify the methods including stipulated values and assumptions that allow the desired parameter to be determined from the inferred measurements. The assessment shall state the means used to arrive at assumptions and stipulated values. The assessment shall state the process used for in-situ validation of assumptions and stipulated values. In keeping with

[1] For additional information, see Nonmandatory Appendix B, Key References, Nos. 3, 6, and 12.

transparency and full disclosure, all instances of reference to indirectly measured parameters shall be clearly identified as inferred values.

For both direct and indirect measurements, the assessment shall document all relevant application data from the manufacturer's instrument specification, e.g., calibration information, accuracy, precision, installation, and application considerations. The assessment shall identify and document any in-situ installation factors that deviate from the manufacturer's recommendations. The assessment shall estimate accuracy and confidence of the in-situ, end-to-end field measurement.

For each instrument used, the assessment shall document the relevant data from the manufacturer's instrument specification, e.g., calibration information, accuracy, precision performance, etc.

5.1.5 Transducer Installation. The assessment shall account for and document the effect of transducer installation factors on the accuracy and confidence of the in-situ, end-to-end field measurement.

5.1.6 Electrical Signal Integrity. The assessment team shall exercise caution when installing measurement systems in classified hazardous areas. The assessment team shall ensure that all components of the measurement system transducers, cables, power supplies, batteries, and data loggers are safety rated to the hazard classification of the area.

The expert shall ensure that electrical signal integrity is protected. If the in-situ environment prevents signal error from being completely eliminated, the effect on measurement accuracy and confidence should be stated.

5.1.7 Planning Measurement Techniques

5.1.7.1 Sample Rate and Data Interval. Sample rate and data interval used by the digital data acquisition system will significantly affect the accuracy of measured data. Consideration shall be given to the assessment objective, action item, and methodology assigned to each measurement. The assessment team shall be responsible for evaluating each measurement to determine the appropriate measurement technique related to sample rate and data interval.

To evaluate dynamic performance, a measurement technique shall use a data interval at least one order of magnitude greater than the time base of the event being measured.

5.1.7.2 Signal Noise. When required, measurement technique shall use existing best practices to minimize the impact of signal noise.

5.1.8 Identify Test Points and Parameters. Measured parameters shall be defined as directly or indirectly measured parameters, including a unique identification of each test point. The assessment team shall document each parameter with a unique identification tag, the parameter measured, and a description of the physical location.

(a) *direct measures:* the assessment team shall identify each test point with an identification tag and parameter to be quantified, along with information about the instrument to be used.

(b) *indirect measures:* the assessment team shall identify indirectly measured parameters and the associated directly measured parameters with an identification tag and information about each instrument to be used.

When preparing transducers for installation, the physical location should be clearly identified on block diagrams and/or drawings and/or documented using digital photos. Replication of measurements for future comparisons of performance data is best accomplished if parameters are measured in identical locations. When preparing the required access connections for measurement test points, the assessment team should recommend that piping connections, electrical connections, and connection points be installed and tagged with the measurement test point's identification.

5.2 Site Access Procedures

The assessment team should finalize logistics and plant site procedures for site access. Details necessary for site access, such as nondisclosure agreements, confidentiality, and security requirements, should already be in place.

The assessment team should finalize logistics of required access to all areas of the plant site at the time(s) of day necessary for assessment activities, including review of routine sign-in, sign-out, badge, ID, escort, etc. The assessment team shall comply with the requirements for access to the plant site, including special procedures for off-shift and/or after-hours site access if required. The assessment team shall coordinate access to any areas with special hazards that, for example, can only be accessed at limited times or require confined space entry precautions, etc.

The assessment team should determine logistics and plant site procedures to allow digital photos and/or video to be taken and comply with plant site-specific safety training and requirements.

5.3 Assessment Kick-Off Meeting

The assessment kick-off meeting shall familiarize participants with the site-specific assessment plan of action and application of the systems approach. Assessment team members should be given authority and responsibility to plan, schedule, and investigate specific objectives and action items.

The assessment team should discuss logistics and scheduling of various elements of the plan of action. The assessment team shall schedule times for investigation and measurement of plant areas and equipment that may have limited availability during which measurement equipment can be installed or removed. The assessment team shall also consider production areas and equipment that may have limited runtime, during which observations and measurements can be made.

5.4 Deploy Data Collection Equipment

The assessment team shall install portable instruments for short-term measurement activities as required by the measurement plan. The assessment team shall record short-term data with a portable digital data acquisition system (data logger). Multiple data loggers independently assign time and date values to logged data. The assessment team shall align the time and date values of each separate data logger as closely as possible and document the expected time variation that will occur between data systems.

The assessment team shall verify that the digital system is reading all transducers at the sample rate and data interval as required by the measurement plan. The assessment team shall also verify that data values are correctly converted to engineering units. This should be accomplished with a short test run of data and a comparison with independent instrumentation where available or a comparison with a group of associated stipulated values and/or indirect measurements.

If data are erroneous, the assessment team shall attempt to troubleshoot and correct equipment and/or instrument installation issues, such that recorded data is appropriate. If erroneous data cannot be corrected, the malfunctioning devices and affected data shall be noted. If unresolved measurement installation issues increase uncertainty with respect to the recorded data, the assessment shall document issues and the impact on measurement confidence level.

5.5 Coordinate Data From Permanently Installed Data Systems

If measurement data from permanently installed instrumentation are included in the measurement plan, the assessment team shall gather assessment data available from permanently installed systems, e.g., supervisory control and data acquisition system (SCADA).[2] If data from short-term measurement activity (logged data) will be used together with SCADA data, the assessment team shall align the time and date values of each separate system as closely as possible. The assessment shall document the expected time variation that will occur between data systems.

The assessment team shall verify that the SCADA is reading the transducer at the sample rate and data interval as required by the measurement plan and convert the values to correct engineering units. If data are erroneous, the assessment team shall troubleshoot and correct equipment and/or instrument installation issues such that recorded data are appropriate. If unresolved measurement installation issues increase uncertainty with respect to the recorded data, the assessment shall document issues and the impact on measurement confidence level.

5.6 Validate Data

As data are collected and before post-processing analysis begins, the assessment team members collecting the data shall validate that data are reasonable and correct.

Collecting large amounts of data may lead to some erroneous or missing data. The assessment team shall document any data loss that occurs. They shall establish reasonable methods such as interpolation or other post-processing of recorded data to apply necessary corrections. The assessment team shall document post-processing correction methods and determine the impact on accuracy and confidence level of the affected parameters. If data loss exceeds a limit agreed to by assessment team members, they shall establish a supplemental measurement plan to acquire the necessary data.

5.7 Plant Functional Baseline

The assessment team shall record data associated with plant function and production process information. Base-year energy use shall be measured according to Mandatory Appendix II, II-1, a., Present Energy Use. To completely define base-year conditions, it is necessary to document the plant's functional baseline through gathering relevant production operating data. These data are the basis of future system performance comparison. The assessment should record plant-operating conditions in a way that can be accessed in the future. Comparisons of future performance will require adjustments for changing plant function, including factors such as production shifts per day and amount and type of products being produced.

5.8 Functional Investigation

5.8.1 Supply. The assessment team shall establish a detailed plan to schedule and perform the necessary observation and measurement of plant operations and compressed supply side performance.

The assessment team shall assess the following:

(a) present energy use, air compressor(s); Mandatory Appendix II, II-1, a.1

(1) present energy use, air dryer(s); Mandatory Appendix II, II-1, a.2

(b) present compressed airflow profile; Mandatory Appendix II, II-2

[2] Permanently installed data systems have various disigtnations, such as Distributed Control System (DCS) Building Management System (BMS), etc. For reference, such systems will be referred to us SCADA.

(c) supply efficiency; Mandatory Appendix II, II-3
(d) system volume; Mandatory Appendix II, II-4, a.1 or a.2
(e) pressure profile, supply; Mandatory Appendix II, II-5, a.1.

5.8.2 Transmission. The assessment team shall establish a detailed plan to schedule and perform the necessary observation and measurement of plant operations and the transmission of compressed air from supply to demand.

The assessment team shall assess pressure profile (Mandatory Appendix II, II-5, a.2).

5.8.3 Demand. The assessment team shall establish a detailed plan to schedule and perform the necessary observation and measurement of plant operations and compressed air end-use applications. The assessment team shall perform site-wide investigation of all assessment action items associated with site-specific assessment goals and the SOW.

The assessment team shall assess the following:
(a) pressure profile, point of use; Mandatory Appendix II, II-5, a.3
(b) perceived high-pressure demands; Mandatory Appendix II, II-6, a., b., and c.
(1) perceived high-pressure demands; Mandatory Appendix II, II-6, d. and e.
(c) demand profile; Mandatory Appendix II, II-7, a.1
(1) demand profile; Mandatory Appendix II, II-7, a.2 and a.3
(2) demand profile; Mandatory Appendix II, II-7, b. and d.
(3) demand profile; Mandatory Appendix II, II-7, c. and e.
(d) critical air demands; Mandatory Appendix II, II-8
(e) compressed air waste; Mandatory Appendix II, II-9
(f) optimize air treatment; Mandatory Appendix II, II-10, a.1, d.1, and g.1
(1) optimize air treatment; Mandatory Appendix II, II-10, a.2, a.3, b., c., e., and f.
(g) improve compressor control; Mandatory Appendix II, II-11
(h) reduce operating pressure; Mandatory Appendix II, II-12
(i) balance supply and demand; Mandatory Appendix II, II-13
(j) maintenance opportunities; Mandatory Appendix II, II-14, a.1, a.3, and b.
(1) maintenance opportunities; Mandatory Appendix II, II-14, a.2, a.4, and c. through g.
(k) heat recovery; Mandatory Appendix II, II-15

5.9 Progress and Wrap-Up Meetings

As a final step in conducting the assessment, all available assessment team members shall be assembled, and a wrap-up meeting shall be conducted. The meeting agenda should address the following two goals:

(a) Communicate findings among team members sharing information and data collected. Evaluate findings to summarize areas of greatest opportunity, and identify priorities for analysis of data.

(b) Evaluate knowledge gained during the system assessment and identify any informational gaps that give rise to questions that require additional investigation. Organize additional assessment activities as warranted.

As directed by plant management or at the discretion of an assigned assessment team member, the assessment team shall convene progress meetings to address the two goals listed above. Progress meetings are particularly useful if, while conducting the assessment, it is determined that there should be discussions related to a change in the assessment plan of action or SOW.

6 ANALYSIS OF DATA FROM THE ASSESSMENT

Using data collected during the assessment, the assessment team shall establish baseline profiles and annualize projections of base-year performance. The assessment shall analyze compressed air supply and demand balance to identify opportunities for improved performance and increased energy efficiency.

The assessment shall evaluate the system pressure profile and identify opportunities to eliminate irrecoverable pressure loss.

The assessment shall analyze dynamic airflow changes and resultant transient pressure profile response to assess the performance impact and possible upset of end-use applications.

The assessment shall include an analysis of end-use applications and specific energy performance opportunities as a result of potential system pressure reduction, elimination of compressed air waste, and improved performance of critical end-use applications.

The assessment shall perform root cause analysis for current method operations to identify energy efficient remedial measures, identify specific energy performance improvement opportunities, and quantify projected energy savings.

6.1 Baseline Profiles

The assessment shall determine baseline performance for the system power profile and the associated airflow rate of demand. The assessment shall determine baseline performance through analysis of energy use and total air demand. The assessment shall baseline the system's compressed air supply efficiency, analyze baseline performance trends, and identify the profile for typical periods of operation. The assessment shall include annualized data for the expected number of operating periods for each typical period profile that has been identified (see para. 6.1.5). The assessment shall include a projection of base-year energy and air demand totals.

6.1.1 Power and Energy Profiles. The assessment team shall evaluate the power response of air compressors to dynamic changes in system performance. The data interval used should be at least one order of magnitude greater than the time base of the control response being analyzed. The assessment shall identify inefficient control response through analysis of individual compressor performance and also the combined response of multiple compressors.

The assessment shall develop hourly energy and air demand totals to establish operating profiles. The assessment shall identify days of operation that have similar energy profiles and correlate with plant functional information.

6.1.2 Demand Profile. The assessment shall analyze dynamic air demand to identify system performance requirements and the resultant air compressor power response. The assessment shall identify periods of inefficient operation that warrant more detailed analysis of the dynamic demand profile.

The assessment shall integrate airflow rate measures over time to represent demand trends and establish operating profiles. The assessment shall identify periods of operation that have similar air demand profiles and correlate with plant functional information.

6.1.3 Supply Efficiency. The assessment shall relate measured power and energy data to measured airflow rate and total air demand to establish baseline compressed air supply efficiency. The assessment shall include an evaluation of the relationship of air demand trends to supply efficiency and identify periods of reduced supply efficiency that warrant more detailed investigation. The assessment team shall analyze system operation to evaluate the supply and demand dynamic balance and compressor control response.

6.1.4 Identify Operating Period Types. The assessment shall correlate total energy and total air demand profiles to plant functional information and establish typical operating periods. The assessment shall create groupings of similar typical operating periods.

6.1.5 Annualize Energy Use and Air Demand. The assessment shall include annual plant profiles to establish base-year performance, total energy use, and total air demand. For each operating period identified, the assessment shall estimate on an annual basis the number of such periods for which the plant uses that profile. The assessment shall include a calculation of base-year totals using each typical operating period profile and number of times the plant is operating at each typical period. Plant energy costs shall be applied to determine annual compressed air energy cost and cost per unit of compressed air.

To calculate base-year performance, the assessment shall define the following:

NOTE: For illustration purposes, the time interval used for typical operating periods is 1 day, a 24-hr period. Any appropriate time period may be used so long as the sum of all time periods fairly represents the total for annual operation.

(a) individual day types (Dt1, Dt2… DtN)
(b) measured energy use (kWh1, kWh2… kWhN) for each day type
(c) total air demand (MMscf1, MMscf2… MMscfN) for each day type
(d) number of operating days per year (DPYr1, DPYr2… DPYrN) for each day type
(e) annual energy use base-year performance
(DPYr1 + kWh1) + (DPYr2 × kWh2) + … + (DPYrN × kWhN)
(f) annual total air demand base-year performance
(DPYr1 × MMscf1) + (DPYr2 × MMscf2) + … + (DPYrN × ζ MMscfN)

6.2 System Volume

The assessment team shall calculate the effective volume of the compressed air system. The effective volume of a compressed air system can be determined through empirical testing. During a period of constant air demand, the assessment team shall load and unload a compressor of known airflow delivery (or measure the airflow change with load/unload cycles), and the assessment team shall also measure the load/unload pressure, along with load and unload time duration. If testing to determine effective volume cannot be accomplished, then the assessment team shall estimate the system's mechanical volume.

6.3 Pressure Profile

The assessment shall identify energy and performance improvement opportunities that result from elimination of irrecoverable pressure loss. An analysis shall be included to determine the impact of airflow variations and interaction with the flow resistance of system components and piping and the resultant dynamic pressure profile response. The pressure profile performance as it affects compressor control response, airflow supply and demand balance, and performance of end-use demands shall be assessed.

Using the cumulative result of all remedial measures related to the system pressure profile, including mitigating the effect of pressure variations, drawdown events, dynamic pressure instability, irrecoverable pressure loss, and excessive end-use dynamic pressure loss; the assessment shall establish specific recommendations for an appropriate system pressure profile.

The recommended pressure profile should account for all pressure requirements from supply to the end-use device. The assessment shall specify each element of the pressure profile.

(a) Compressor control pressure range, including accommodation for multiple compressor control strategy.

(b) Treatment equipment pressure drop considering peak airflow rate and the greatest pressure drop through filters when element change is recommended.

(c) Primary storage pressure differential given the recommended storage volume and the necessary usable mass flow of compressed air to support efficient compressor control, permissive start-up time for stand-by compressors, and demand events.

(d) Transmission pressure loss to one or more sectors of the plant site considering peak airflow rate to each various sector. Pressure loss should be inclusive of pipeline pressure gradient, pressure drop through treatment equipment, and pressure differential for applied secondary storage within the transmission system.

(e) Point-of-use pressure profile considering the flow static or flow dynamic characteristic of end use. Point-of-use pressure profiles shall be inclusive of pressure loss from the equipment connection point through point-of-use treatment equipment, piping, and controls. If secondary storage is recommended, the pressure profile shall indicate the necessary storage pressure differential.

The assessment shall state the recommended demand side target pressure and pressure variation tolerance for each various demand sector. The assessment shall provide a control strategy to align supply with demand and maintain alignment throughout normal variations in the demand profile.

6.3.1 Average Pressure and Pressure Variations. The assessment team shall analyze the system pressure profile using data collected during the assessment. The assessment shall determine average system pressure correlation with energy and total air demand profiles. The assessment shall investigate dynamic pressure variations and correlate them to supply-and-demand airflow balance. The assessment shall identify characteristic signatures of system events that warrant more detailed investigation and opportunities to improve the supply-and-demand balance with application of storage and quantify the energy benefit resulting from pressure profile improvement.

6.3.2 Peak Airflow — Effect on the Pressure Profile. Peak airflow and the resultant pressure drawdown and/or pressure instability can cause the pressure profile to fall below the plant's minimum system pressure requirement. Increasing the overall system pressure to accommodate pressure drawdown and pressure instability can be a very energy intensive solution. The assessment shall perform root cause analysis to identify the cause-and-effect relationship associated with the pressure profile's interaction with peak airflow. The assessment shall investigate specific remedial measures of storage and/or reduced system resistance. The assessment shall identify the anticipated performance impact and quantify the energy benefit resulting from pressure profile improvement.

6.3.3 Excessive Irrecoverable Pressure Loss. The assessment shall determine pressure drop associated with various system components and correlate data from dynamic pressure and demand profiles. The assessment of component pressure drop shall be correlated with periods of low, average, and peak air demand. The assessment shall identify remedial measures to reduce airflow rate through elimination of waste and inappropriate use or application of secondary storage with controlled refill to reduce peak demand. With projections of reduced airflow rate, the assessment shall recommend the size and application of system components for proper airflow capacity.

Considering the entire compressed air system — supply, transmission, and demand — the assessment shall identify specific remedial measures and estimate the performance impact and energy benefit of pressure profile improvements.

6.3.4 Excessive Pressure Gradient. The assessment shall include an analysis of pipeline pressure gradients and identify if excessive pressure loss at the current airflow rate is a function of high pipeline velocity and distance traveled or if restrictive choke points exist. The assessment shall identify sectors of the transmission system presenting excessive pressure loss. If excessive pressure gradient is identified, the following supplemental element of assessment shall be performed.

The assessment shall evaluate air demand in the affected sector(s) to identify remedial measures that will decrease airflow rate to the sector through elimination of waste and inappropriate use or application of secondary storage with controlled refill. With projections of reduced airflow rate through the affected pipeline, the assessment team shall calculate the expected pressure gradient associated with the reduced air demand. The assessment shall identify specific remedial measures for sector demand reduction, piping modifications to eliminate choke points, opportunities to create piping loop connections to existing pipelines having unused flow capacity, or complete pipeline redesign.

The assessment shall estimate the performance impact and energy benefit of pressure profile improvements.

6.4 Perceived High-Pressure Demand

Using data gathered during the assessment, the assessment team shall validate the end-use pressure requirement for all applications identified according to Mandatory Appendix I, I-4, d. Perceived high-pressure demands often set the low limit for the plant's minimum system pressure. Lowering the system pressure profile presents energy reduction opportunities. The perceived need for high pressure at any individual end-use demand may be the result of many factors.

(a) Casual reference to general operating data for the end-use demand may give rise to a perceived pressure requirement not necessary for the actual end-use application.

(b) The end-use air demand performance may be the result of systemic issues that are the root cause of the perceived need for high pressure.

6.4.1 Rated/Recommended End-Use Pressure. The assessment team shall research recommended operating data for the end-use compressed air demand in the context of in-situ performance requirements. The assessment team shall check to verify that general operating data do not overstate the pressure requirement for the actual production function being accomplished. The assessment shall verify recommended end-use pressure in the context of the "as-installed," end-use requirement.

6.4.2 Dynamic Flow/Pressure Relationship. The assessment shall include analysis of the dynamic performance of the end-use demand, using high-frequency data gathered during the assessment. This includes investigating the dynamic point-of-use pressure profile from the equipment connection pressure to the subject end-use device. The assessment shall evaluate the nature of the end use as flow static or flow dynamic demand. The assessment shall assess the appropriateness of the current end-use pressure profile and dynamic pressure signature.

6.4.3 Stability of Supply Pressure. The assessment team shall assess the stability of pressure delivered at the equipment connection point. Pressure instability can be caused by dynamic performance of the transmission system or the impact of other system events on the equipment connection pressure. The assessment shall rule out upstream pressure instability as a reason for perceived high-pressure requirements.

6.4.4 Remedial Measures and Quantify Savings. The assessment shall identify specific remedial measures addressing high-pressure air demands and estimate the performance impact and energy benefit of pressure profile improvements.

6.4.4.1 Existing Pressure Anomalies. If the root cause of perceived need for high pressure is a result of systemic or point-of-use pressure anomalies, the assessment team shall investigate remedial measures to address the root cause issue.

6.4.4.2 Valid High-Pressure Use. If the end use is a valid high-pressure demand representing a small fraction of total air demand, and is driving the system pressure profile to excessively high pressure, the assessment team shall investigate alternatives that will reduce system energy consumption. The assessment shall analyze the potential to modify the end-use device to allow successful operation at lower supply pressure. If it is not feasible or cost effective to modify the end-use device, the assessment team shall propose an alternative means to supply the air demand, such as a small dedicated independent air system, application of pneumatically powered air amplifiers, or an electrically driven booster compressor.

6.5 Demand Profile

The assessment shall identify energy and performance improvements that relate to the compressed air demand profile. The assessment shall evaluate the potential for demand reduction, improving the supply-and-demand balance and optimizing the compressor control response to normal variations in air demand. The assessment shall analyze the combined performance of the supply system (generation and storage), transmission system, and point-of-use equipment to identify opportunities to better control and support the system's demand profile. The assessment shall identify specific remedial measure(s) to exercise compressed air demand management and quantify estimated energy savings.

6.5.1 Average Airflow and Airflow Variations. Using data gathered during the assessment, the air demand profile, including its correlation to the energy profile and average system pressure, shall be identified. Periods of high and low demand shall be identified and the system's ability to maintain an optimum supply-and-demand balance. The assessment shall identify any specific periods of operation that warrant more detailed analysis.

The assessment shall analyze periods of supply-and-demand imbalance and identify specific remedial measures to better align supply and demand. The assessment shall consider measures necessary to maintain alignment throughout normal changes in the plant's compressed air demand.

The assessment shall include a review of airflow variations and the dynamic performance of system air demand together with the system's dynamic pressure profile. Demand events and system response, including pressure drawdown rate and airflow contribution of storage, shall be analyzed. The assessment shall include a quantification of demand events and their total airflow rate and duration. The assessment team shall investigate the characteristic signatures of repeated events and, if possible, correlate the event to the associated production equipment and/or activity.

6.5.2 Transmission System Performance. The assessment team shall assess the performance of transmission during demand events and identify any ripple effects on the system pressure profile. The assessment shall analyze how demand events are reflected in control signal pressure and the resultant supply side response. The assessment team shall determine whether compressor controls respond in an efficient manner. The assessment shall analyze how demand events are reflected in the connection pressure at end-use applications. The assessment shall determine whether there is any adverse effect of pressure variation at end-use demands.

6.5.3 Remedial Measures and Quantify Savings. The assessment shall evaluate alternatives of improved compressor control, primary/secondary storage, and flow pressure control to more efficiently deal with airflow variations that occur. The assessment shall identify specific remedial measures and quantify the expected energy reduction.

6.6 Critical Air Demands

Critical air demands are those end uses of compressed air that have the potential to impact product quality, production rate, scrap rate, rework cost, customer satisfaction, etc. As such, improving performance of critical air demand is most relevant in terms of nonenergy benefits to production operations. However, there are often energy-related benefits associated with improving performance of critical air demands.

6.6.1 Effect on Productivity and Energy. Given the secondary role of energy reduction when analyzing critical air demands, it is important to consider the positive effect on productivity and associated financial benefit of improved performance. In this situation, the plant functional baseline as relates to production output is of relatively greater importance than the energy consumed.

For situations where energy use is increased, energy analysis is more involved than the straight forward baseline versus postimplementation energy comparison. Alternative energy analysis methods used should be reached through consensus of all stakeholders. Analytical methods used should be transparent and fully disclosed.

6.6.2 Critical End-Use Characteristics. Analysis of a critical air demand will benefit from defining the flow and pressure characteristics of this demand. The assessment shall determine whether compressed air system performance related to the critical end use should be considered as a process variable.

For critical end-use applications, the dynamic performance and characteristic signatures for airflow and/or critical end-use pressure shall be documented. Dynamic data should be recorded at a data interval frequency not less than one order of magnitude greater than the time base of the critical end-use event. The assessment shall include an analysis of end-use function data and performance, comparing characteristic signatures for periods of normal operation with periods of unsatisfactory operation.

The assessment team shall perform root cause analysis to identify issues impacting critical compressed air performance. Analysis should also consider and, if possible, rule out other causes, such as mechanical vibration or reactionary force acting on the end-use pneumatic device. In some instances, the result of analysis may be to rule out compressed air-related performance as a causative effect.

The assessment shall include an analysis of the end-use function to quantify the value and allowable tolerance for end-use pressure and/or airflow rate necessary to properly support the end-use application.

6.6.3 Analyze Process Limits. The assessment team shall determine the need to provide monitoring and control of compressed air as a process variable. If necessary, the assessment team shall establish process constraints with appropriate methods of process monitoring, alarm indicators, and documentation of performance.

6.6.4 Remedial Measures and Quantify Savings. The assessment team shall identify specific remedial measures for critical air demands and quantify the expected cost savings. As required, the assessment team shall identify measures required to implement process monitoring. A financial analysis shall include the cost of control and monitoring. The net savings shall include the productivity impact and net energy change from implementing the remedial measures.

6.7 Compressed Air Waste

Using data collected during the assessment, the various components of compressed air waste shall be identified. Specific remedial measures necessary to eliminate waste shall be provided, and energy savings estimates for each remedial measure shall be calculated.

6.7.1 Leakage. The total amount of leakage present in the system shall be estimated. The assessment team shall make observations with respect to the existing piping and maintenance practice as relates to the relative number and size of leakages. It can be expected that greater leak reduction is achievable when there are relatively fewer large leaks as compared with numerous small leaks. Numerous small leaks may be a result of widespread use of poor piping practice in which small leaks are likely to occur. Specific recommendations shall be developed to address any existing poor piping practice.

The assessment team shall establish short-term leak reduction targets and recommendations of specific remedial actions to achieve the targeted leak reduction. For the leak reduction target, estimated energy savings shall be provided.

6.7.2 Inappropriate Use. Using data gathered during the assessment, inappropriate uses shall be identified, and alternatives shall be provided. The assessment team shall calculate the projected energy use of alternative methods and shall estimate total net energy savings from the implementation of the identified alternative methods.

6.7.3 Artificial Demand. Using demand side pressure data gathered during the assessment and the established demand side target pressure resulting from the recommended system pressure profile, the potential reduction in artificial demand shall be calculated. The assessment shall include an outline of specific remedial measures necessary to achieve and maintain the established demand side target pressure for the system (or each demand sector) and the estimated energy savings from implementing such remedial measures.

6.8 Optimize Air Treatment

The assessment team shall determine a system-wide compressed air treatment strategy considering end-use requirements, the current method of compressed air treatment, and pressure dew point data gathered during the assessment. The energy and performance improvement opportunities resulting from specific remedial measures recommended to optimize air treatment shall be identified. The assessment shall include estimated energy savings for the optimized air treatment strategy as compared with the present method of operation.

6.8.1 Appropriate Air Quality. Considering existing end-use applications of compressed air and their respective air quality requirements, allowable contamination levels for particulate, dew point, and hydrocarbons in the compressed air shall be established. Allowable contamination levels should be specified in accordance with ISO 8573-1, Compressed air — Contaminants and purity classes.

6.8.2 Redundant Treatment Equipment. The assessment team shall evaluate the application of redundant air treatment equipment and end-use risk factors. The assessment shall include an appropriate strategy to eliminate any unnecessary air treatment equipment while ensuring that risk management objectives and stakeholder needs are satisfied.

6.8.3 Treatment Effect on Pressure Profile. The assessment team shall evaluate the existing application of air treatment equipment and its impact on the system pressure profile. Opportunities to eliminate irrecoverable pressure loss shall be identified. This shall include an analysis of the dynamic interaction of supply side air treatment equipment resistance with the compressors' changing airflow delivery and the impact on control signal pressure.

The assessment team shall evaluate the pressure loss associated with the air treatment equipment within the transmission system and assess its effectiveness. If it is found that the unacceptable contaminants could be introduced downstream from the transmission system's air treatment equipment, the assessment team should consider whether it is more appropriate to perform the necessary air treatment in closer proximity to the end-use requirement.

The assessment team should evaluate point-of-use treatment equipment to verify that it is required and appropriate in the purity class produced. The assessment team shall analyze the treatment equipment's impact on the dynamic pressure profile and determine whether it is suitably sized to support peak airflow rate of the end-use application while operating with a reasonable pressure loss.

6.8.4 Remedial Measures and Quantify Energy Result. The assessment team shall develop a system-wide compressed air treatment strategy, including specific remedial measures to optimize compressed air treatment. The assessment shall include recommendations for supply side treatment, sectioning of independent air treatment sectors if appropriate, air treatment applied to the transmission system, and/or point-of-use air treatment recommendations.

Based on measurements made and data collected during the assessment, the present energy use of the existing method of compressed air treatment shall be calculated. Considering the energy use of the proposed compressed air treatment strategy, the assessment team shall estimate the net energy savings as compared with the existing method.

6.9 Reduce System Operating Pressure

The assessment team shall establish the recommended target pressure for system operation. The assessment shall include an analysis of the recorded system pressure profile and apply the cumulative result of all remedial measures related to the system pressure profile, including mitigating the effect of pressure variations, drawdown events, dynamic pressure instability, irrecoverable pressure loss, and excessive end-use dynamic pressure loss, and establish specific recommendations for an appropriate system pressure profile.

The assessment shall include the recommended demand side target pressure and pressure variation tolerance for each various demand sector. The assessment team shall evaluate system operation at the reduced target pressure and estimate the energy use reduction associated with the reduced target pressure.

6.10 Balance Supply and Demand

The assessment team shall analyze the compressed air system control methods necessary to maintain real-time balance between supply and demand with sufficient transmission capacity to move compressed air energy from supply to demand as required by the dynamic characteristics of the system.

The assessment shall include an evaluation of the application of primary and/or secondary storage with appropriate control to support peak air demand and delay or eliminate the start-up of additional compressor capacity in response to short-term demand events.

The assessment team shall analyze the total impact of compressed air demand reduction, including the elimination of inappropriate uses, leakage, and artificial demand, together with the impact of the recommended compressed air storage to reduce peak airflow supplied from generation. Given the baseline demand profile, the assessment team shall estimate the projected demand profile with the implementation of recommended measures. This analysis shall optimize compressor control strategy to the projected demand profile, including considering the following:

(a) Shutdown any compressors that are not needed to support the reduced demand profile.

(b) Where possible, operate compressors at their most efficient performance condition, which is typically at their full load design point.

(c) Apply trim compressor capacity operating with the most efficient part-load capacity given the available mix of compressor sizes and control types.

(d) In multiple compressor systems, consider applying control automation to maintain supply-and-demand balance under normal variations in the demand profile.

The assessment team shall identify the necessary remedial measures to implement any proposed control strategy. The expected reduction in energy use savings shall be quantified.

The assessment team should consider that implementation of remedial measures will likely occur as an ongoing process phased in over time. The assessment shall include a description of the control strategy's flexibility to efficiently meet the demand profile as it may change within various stages of implementation. If specific changes to the design and implementation of the control strategy are necessary during the implementation of remedial measures, the assessment shall include appropriate milestones and anticipated changes that must be implemented.

6.11 Assess Maintenance Opportunities

The assessment team shall evaluate maintenance performed on the compressed air system and its effect on energy efficiency, performance, and reliability of the system. The team shall evaluate maintenance and installation of the compressor intake filter and piping to assess the impact on compressor capacity, reliability, and efficiency. Installation and maintenance of condensate drain traps shall be investigated to assess compressed air waste and energy loss associated with improper operation of condensate drains.

Supplemental elements of assessment as determined in the site-specific assessment SOW may direct the assessment team to evaluate other maintenance opportunities. The assessment team shall identify opportunities to improve performance and reliability and shall estimate the impact on total energy use.

Air compressor cooling frequently affects performance and reliability. If the site-specific SOW includes maintenance actions affecting compressor cooling, the assessment team shall evaluate the interaction with other systems, such as heating, ventilation, and air conditioning (HVAC) equipment, which may impact performance and reliability.

The assessment team shall recommend specific remedial measures and estimate energy reduction. Recommendations shall consider that sustainable results related to maintenance opportunities frequently require ongoing maintenance programs to be implemented. Remedial measures shall promote sustainable improvement of system performance and energy efficiency.

6.12 Evaluate Heat Recovery Opportunities

The assessment team shall analyze the annual operating profile for applications that could potentially use heat recovered from the air compressors. Based on a conceptual design of a suitable heat transfer system, the assessment shall include an estimate of the amount of recoverable heat. This analysis shall determine the net energy reduction accounting for energy use of auxiliary fans, pumps, heat pumps, or other equipment associated with a heat transfer system.

7 REPORTING AND DOCUMENTATION

7.1 Final Assessment Report

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

7.2 Final Assessment Report Contents

The final assessment report shall include the following information:

(a) executive summary
(b) facility information
(c) assessment goals and scope
(d) description of system(s) studied in assessment and significant system issues
(e) assessment data collection and measurements
(f) data analysis
(g) 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 production process and present plant operation, 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) recommendations for implementation activities

7.2.2 Facility Information. A brief overview of the production process and summary of the present production operations and plant output level. A detailed description of the facility, plant background, and products made at the plant.

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. Using Mandatory Appendix II (Plan of Action Matrix), the system assessment objectives, action items, and methodologies that were used for the Plan of Action shall be described.

7.2.4 Description of System(s) Studied and Significant System Issues. The report shall include a detailed description of the specific system(s) on which the assessment was performed. 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 the system. Any existing best practices found (methods and procedures found to be most effective at energy reduction) shall be documented.

A one-line block diagram or other visual portrayal that depicts both the supply and demand sides shall be included and shall include identification of the monitoring and measurement points. Any significant system issues shall be described, including an operational review of the system, demand side issues, transmission issues, and supply side issues.

7.2.5 Assessment Data Collection and Measurements. The methods used to obtain data and conduct measurements shall be identified, including an overview of the measurement plan. Measurement data and observations required for para. 7.3 not reported in para. 7.2.6 shall be placed in an appendix.

The assessment report or appendix shall describe measurement details to provide consistency, repeatability, and reproducibility of measurements during the assessment and for future measurement and verification activity. The assessment report shall 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 your site-specific assessment goals, assessment plan of action, and SOW. Any significant analytical methods, measurements, observations, and results from data analysis from completed action items shall be documented, including but not limited to

(a) power consumption of the compressors
(b) compressor control response
(c) compressed airflow delivered to the system in scfm
(d) supply efficiency in specific power (kW/100 standard cubic feet per minute, or compressed air supply efficiency, such as standard cubic feet (scf) per unit of energy (kWh)
(e) air treatment
(f) critical air demands
(g) compressed air waste
(h) condensate drainage
(i) air pressure leaving the supply side of the system in pounds per square inch gage (psig)
(j) supply side pressure profile
(k) demand side pressure profile
(l) transmission/distribution piping gradients
(m) end-use applications assessed for appropriateness, high-volume intermittent, and high pressure
(n) heat recovery
(o) safety issues

The assessment report shall identify the methods of calculation and software models used with assumptions clearly stated.

Unremarkable findings should not be included in the report. However, pertinent negative findings shall be reported.

7.2.7 Annual Energy Use Baseline. The assessment report shall contain annualized base-year performance for total compressed air demand and energy use of the compressed air system. The analytic method used to develop the annual base-year projection from measured baseline data shall be described. Plant functional and production process observations and information shall be reported. This section shall provide a description of the plant's functional areas, baseline production output level, and operating schedule during the baseline period. Information describing normal production variations shall be reported.

The report shall clearly describe the assessment baseline as a basis for both routine and nonroutine 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 plant 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- and time-dependent compressed air energy consumption and compressed air demand 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 pneumatically powered equipment are examples of nonroutine adjustments.

7.2.8 Performance Improvement Opportunities Identified and Prioritization. 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.

The analysis shall quantify estimates of energy reduction and cost savings from recommended performance improvement opportunities, as well as the total energy reduction and cost savings.

To aid in the selection of projects for implementation, the assessment team should provide information with respect to factors that influence prioritization of opportunities identified.

The report shall provide information with respect to the following categorical characteristics:

(a) energy reduction and cost savings with confidence level and precision interval

(b) potential barriers to achieving projected savings

(c) statement of anticipated project life and sustainability

(d) potential impact to ongoing operations

(e) description of implementation steps and barriers to implementation

(f) anticipated parallel benefits (e.g., improved productivity, improved operations, lower environmental impact)

(g) environmental impact that may trigger reanalysis of environmental requirements at the plant

Nonenergy opportunities, such as production output level improvement, emission reductions, and product quality improvements, shall be identified.

General observations of noncompressed air 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.

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.

Examples include software tools used and progress and wrap-up meeting information, such as participants and content. Appendices should include titles such as "Appendix A: Measurements Obtained During Assessment" or "Appendix B: Example Calculations."

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 6 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.

MANDATORY APPENDIX I
PRELIMINARY DATA COLLECTION MATRIX

The purpose of the matrix is to present assessment objectives, action items, and methodologies. Some are required elements of an assessment that is fully compliant with this Standard. Supplemental elements including other objectives, action items, and methodologies can be included at the discretion of assessment team members.

Required elements: assessment objective, action item, and methodology are shown in Mandatory Appendix I using black text on white background, as shown here. Each required element, assessment objective, and action item shall be investigated using one or more methodologies also shown as black text on white background.

Users of this Standard may decide that in addition to required elements, their technical and business objectives will benefit by including some supplemental assessment activities. Based on the assessment team's expertise and judgment, supplemental assessment activities may be included in the assessment. Once a supplemental element is included in the assessment SOW, it is a required element, and the applicable requirements of the Standard shall apply.

NOTE: Shaded items are supplemental elements for an assessment.

Methodologies that potentially apply to their associated action item are marked with an **X**. If a methodology is not applicable to a particular action item, "na" appears in the column for that methodology.

I-1 PLANT BACKGROUND

Document plant background information including a brief description of manufacturing processes and products. Document the company's markets, employees, revenue, and general business climate.				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.								
System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Describe the plant's overall manufacturing process.	1)	Identify NAICS Code.	**X**	na	na	na	na
		2)	Identify raw materials used.	**X**	na	na	na	na
		3)	Document an overview description of the manufacturing process.	**X**	na	na	na	na
		4)	Describe the finished product(s).	**X**	na	na	na	na
b.	Describe plant's products and markets.	1)	Identify the standard measurement of production volume by product.	**X**	na	na	na	na
		2)	Document packing and shipping methods.	**X**	na	na	na	na
		3)	Describe typical markets served.	**X**	na	na	na	na
c.	Describe the company's size.	1)	Identify size, e.g., number of employees, annual revenue, market position, etc.	**X**	na	na	na	na
d.	Describe the general business climate.	1)	Identify present business climate, industry sector performance, and market outlook.	**X**	na	na	na	na

I-2 PLANT FUNCTION

Describe the plant's location, size, and ambient/environmental conditions and the compressed air system's functional attributes.				Methodology				
				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
NOTE: Shaded items are supplemental elements for a system assessment.								
System Assessment Objective		System Assessment Action Item						
a.	Plant site information.	1)	Location	X	na	na	na	na
		2)	Elevation, ambient conditions	X	na	na	na	na
		3)	Size, sq ft, number of employees, etc.	X	na	na	na	na
		4)	Environmental conditions in compressor equipment and production areas, e.g., temperature, humidity, hazards, classified areas, dusty conditions, etc.	X	na	na	na	na
		5)	Describe site (site map) single/multi-building, production departments, business units, etc.	X	na	na	na	na
b.	Production process information.	1)	Describe production process by functional areas.	X	na	na	na	na
		2)	Production level	X	na	na	na	na
		3)	Operating Schedule for various shifts, departments, business units, etc.	X	na	na	na	na
		4)	Production variations, typical operating days, seasonal changes, market variations, etc.	X	X	na	na	na
c.	Facility Specialists' interviews to discuss system operation with various stakeholders within the facility. Evaluate system information gained from each stakeholder's perspective to identify and prioritize opportunities for energy savings and performance improvement. Tabulate the opportunities and identify particular system areas, components, equipment, and processes that should be included in the Plan of Action (see para. 4.8 for more detailed investigation).	1)	Interview facility operations personnel regarding overall system operation and areas of concern. Tabulate specific concerns, and prioritize them for further investigation.	X	na	na	na	na
		2)	Interview operators of supply side equipment to determine the nature of routine operations. Identify operational anomalies, their frequency of occurrence, and the severity of impact on energy efficiency, system performance, and reliability. Discuss historical performance issues that are known to have occurred and the resultant design and/or operational measures that have been implemented. Tabulate operational considerations, and prioritize them for further investigation.	X	na	na	na	na
		3)	Interview production personnel from the various production areas to learn how the compressed air system can best support production operations. Identify specific concerns, and prioritize them for further investigation.	X	na	na	na	na
		4)	Interview maintenance personnel responsible for each area of the compressed air system, supply, transmission, and demand/point of use to identify specific concerns, and prioritize them for further investigation.	X	na	na	na	na
		5)	During interviews with all personnel, discuss potential heat recovery, and identify existing energy use that has the potential to be offset with heat from the air compressors.	X	na	na	na	na

I-2 PLANT FUNCTION (Continued)

d.	Energy information.	1)	List primary energy sources, and quantify annual energy use for each.	**X**	na	na	na	na
		2)	Review primary energy cost used to power air compressors. Establish cost per unit of energy to be used for system assessment cost analysis.	**X**	na	na	na	na
		3)	Identify secondary energy resources (in addition to compressed air).	**X**	na	na	na	na
		4)	Describe the present method used for compressed air energy and operating cost accounting.	**X**	na	na	na	na
		5)	Describe on-site energy production.	**X**	na	na	na	na
e.	Energy awareness and organizational energy management initiatives.	1)	Generalize energy awareness for all energy systems.	**X**	na	na	na	na
		2)	Generalize energy awareness of compressed air energy use.	**X**	na	na	na	na
		3)	Identify past and present initiatives related to energy awareness training.	**X**	na	na	na	na
		4)	Identify, review, and summarize previous compressed air-related studies, baselines, or benchmarking.	**X**	na	na	na	na
		5)	Identify existing best practices. Review and summarize previous system design, and upgrade projects that have been approved, initiated, and/or implemented.	**X**	na	na	na	na
		6)	Identify existing compressed air management initiatives, including, leak repair, maintenance, performance monitoring, management information systems/reporting, etc.	**X**	na	na	na	na
f.	Maintenance and operating information.	1)	Summarize existing maintenance program, the process for scheduling, and equipment included in any existing routine maintained program.	**X**	na	na	na	na
		2)	Generalize compressor package operation and maintenance condition, including cleanliness of heat exchanger surfaces and condition of lubricant, lubricant separator, lubricant filter, lubricant level, and air intake filter.	**X**	na	na	na	na
		3)	Generalize the compressor package's function of installed gages, temperature transducers, and other operational instruments and displays.	**X**	na	na	na	na
		4)	Observe and document the compressor's drive motor, cleanliness, and operating environment.	**X**	na	na	na	na
		5)	Generalize the operating condition of treatment equipment, including heat exchange surface cleanliness, and pressure drop through filters and dryers.	**X**	na	na	na	na
		6)	Generalize the function of installed gages, temperature transducers, and other operational instruments and displays.	**X**	na	na	na	na
		7)	Identify the frequency of and process for routine checks on supply side equipment.	**X**	na	na	na	na
		8)	Identify the frequency of and process for routine checks on transmission equipment.	**X**	na	na	na	na
		9)	Identify the frequency of and process for routine checks on demand side and point-of-use equipment.	**X**	na	na	na	na
		10)	Identify sources of inefficient operation, and review obvious signs of repair and operation improvement opportunities.	**X**	na	na	na	na
		11)	List specific maintenance opportunities recommended for further investigation.	**X**	na	na	na	na

I-3 COMPRESSED AIR SYSTEM DEFINITION

Define the plant's compressed air system(s), including the scope of the system's supply side, transmission equipment, and demand side characteristics.			Methodology				
			Observe — Research	Spot Check	Data Logging	Trending	Dynamics
NOTE: Shaded items are supplemental elements for a system assessment.							
System Assessment Objective		System Assessment Action Item					
a. Document the system configuration. Include information on each wholly separate system (systems that are completely separate and isolated from any other system). Any "independent" systems that are interconnected in any manner should be considered as a single system with multiple sectors.	1)	Develop a site-wide block diagram showing the relative locations of separate supply points and the various production areas (buildings, departments, business units, etc.) that are served by the system. Identify various end-use demands and their location, and note any high energy use equipment, processes, and/or production areas.		X	na	na	na	na
	2)	Document individual compressor model and S/N information, along with performance information, as per CAGI Compressor Data Sheets.		X	na	na	na	na
	3)	Document individual treatment equipment components, including model and serial number information, along with performance information, as per CAGI Equipment Data Sheets. Note the location of treatment equipment, supply, transmission, and demand/point-of-use installation. Indicate the location on the system's block diagram.		X	na	na	na	na
	4)	Document individual air storage receivers, including size and working pressure. Include vessel pressure code certification information. Note the air receiver's location, supply, transmission, and demand/point-of-use installation. Indicate the location on the system's block diagram.		X	na	na	na	na
	5)	Document "typical" air uses, and note the location and number of end-use applications that have similar functional and air-use characteristics.		X	X	na	na	na
b. Document existing system controls and performance monitoring equipment.	1)	Identify individual compressor control types and any existing central system master and/or network controls. Identify which individual pieces of equipment (e.g., compressors, dryers) are, and are not, integrated with the system's existing controller.		X	na	na	na	na
	2)	Within the supply side and mainline piping of the transmission system, identify any existing control valves, including their location, performance rating, and function. Typical valves might include check, isolation/crossover, back pressure, and pressure/flow controls.		X	na	na	na	na
	3)	For areas and equipment selected for detailed study (see Mandatory Appendix I, I-2, c.), identify control valves, including their location, performance rating, and function.		X	na	na	na	na
	4)	Identify any existing system transducers providing performance monitoring and/or control input to the system. Identify their location and function. Sensor might include switches sensing, pressure, temperature, flow, etc. Also include transducers that may be sensing, pressure, temperature, flow, kW, dew point, or other operating parameters.		X	X	na	na	na
	5)	Identify and list device tags for compressed air system transducers and/or controls that are included as inputs or outputs associated with an existing DCS, BMS, or SCADA system (Distributed Control System, Building Management System, or Supervisory Control And Data Acquisition system).		X	X	na	na	na
	6)	Include control components in the system's block diagram. Summarize existing control strategies for supply, transmission, and demand/point-of-use operation.		X	na	na	na	na

I-4 INVENTORY KEY END-USE AIR DEMANDS

Based on information gathered during the investigation associated with Mandatory Appendix I, I-2, Plant Function, and I-3, Compressed Air System Definition, tabulate end-use air demands to identify and prioritize opportunities for energy reduction, performance improvement, and increased system reliability. Establish energy use and system performance impact threshold used to segregate and prioritize specific end-use applications for further, more detailed study.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment .		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	High-energy use equipment using large volumes of compressed air. Identify applications to receive further, more detailed study.	1)	Identify equipment and process requirements using large amounts of compressed air.	X	X	na	na	na
		2)	Estimate operating time and the resultant annual energy use.	X	X	na	na	na
		3)	Consider the end-use effect on system performance, including supply, transmission, and other end-use applications.	X	X	X	na	na
b.	High-volume intermittent end-use applications. Identify applications to receive further, more detailed study.	1)	Identify equipment and process requirements using large amounts of compressed air for short periods of time, followed by an interval of time with minimal air demand.	X	X	X	na	na
		2)	Consider the end-use effect on system performance, including supply, transmission, and other end-use applications.	X	X	X	na	na
c.	Potentially inappropriate use. Identify applications to receive further, more detailed study.	1)	Identify potentially inappropriate uses of compressed air. Consider possible alternative energy technologies. Plan and prioritize further study methodology (see Mandatory Appendix II, II-9, b.).	X	X	na	na	na
d.	Perceived high-pressure use. Identify applications to receive further, more detailed study.	1)	Identify perceived high-pressure use that influences the system's present operating pressure. Plan and prioritize further study methodology (see Mandatory Appendix II, II-6).	X	X	X	na	na
e.	Low-pressure use.	1)	Identify low-pressure end-use demands that are supplied using high-pressure compressed air regulated or throttled to low pressure.	X	X	X	na	na
f.	Poorly performing applications.	1)	With information gathered during Facility Specialists' Interviews (Mandatory Appendix I, I-2, c.), identify poorly performing, unreliable end-use applications. Plan and prioritize further study methodology (see Mandatory Appendix II, II-8, Critical Air Demands).	X	X	X	na	na
g.	End-use applications with air quality issues.	2)	With information gathered during Facility Specialists' Interviews (Mandatory Appendix I, I-2, c.), identify end-use applications operating with unacceptable air quality. Plan and prioritize further study methodology (see Mandatory Appendix II, II-10, Optimize Air Treatment).	X	X	X	na	na

I-5 HEAT RECOVERY

Identify existing heating applications with the potential to use heat rejection from the compressor to offset existing energy use.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Energy using applications that have the potential to use heat rejected by the air compressors.	1)	With information gathered during Facility Specialists' Interviews (Mandatory Appendix I, I-2, c.5), identify applications with heat recovery potential. Plan and prioritize further study methodology (see Mandatory Appendix II, II-15, Heat Recovery).	X	X	na	na	na

MANDATORY APPENDIX II
PLAN OF ACTION MATRIX

The purpose of this matrix is to present assessment objectives, action items, and methodologies. Some are required elements of an assessment that is fully compliant with this Standard. Supplemental elements including other objectives, action items, and methodologies can be included at the discretion of assessment team members.

Required elements: assessment objective, action item, and methodology are shown in Mandatory Appendix II using black text on white background, as shown here. Each required element, assessment objective, and action item shall be investigated using one or more methodologies also shown as black text on white background.

Users of this Standard may decide that in addition to required elements, their technical and business objectives will benefit by including some supplemental assessment activities. Based on the assessment team's expertise and judgment, supplemental assessment activities may be included in the assessment. Once a supplemental element is included in the assessment SOW, it is a required element, and the applicable requirements of the Standard shall apply.

Methodologies that potentially apply to their associated action item are marked with an **X**. If a methodology is not applicable to a particular action item, "na" appears in the column for that methodology.

II-1 PRESENT ENERGY USE

Quantify and document the system's present package power consumption of each air compressor (kW), total energy use (kWh), and cost. Quantify and document the power input to auxiliary supply side equipment, air dryers, ventilation fans, cooling pumps, etc. Using a baseline period as required in para. 5.1.3, annualize estimated base-year energy use and cost. (Use cost per unit of energy determined as per Mandatory Appendix I, I-2, d.2.) NOTE: Shaded items are supplemental elements for a system assessment.				Methodology				
System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Determine package power of each compressor to evaluate control response. Baseline energy use and cost for the current method of operation. Assess various typical operating periods to annualize the baseline and establish base-year energy use.	1)	Take measurements to determine package power consumption of all air compressors, and quantify total energy consumption. Record the energy baseline profile for various typical periods of operation.	na	**X**	**X**	**X**	**X**
		2)	Determine power consumption of all air dryers, and quantify total energy consumption. Record the energy baseline profile for various typical periods of operation.	X	**X**	**X**	**X**	**X**

II-2 PRESENT COMPRESSED AIRFLOW PROFILE

Quantify and document the overall compressed air demand rate of airflow (scfm) supplied to the system. Using a baseline period as required in para. 5.1.3, annualize base-year compressed air demand (MMscf). NOTE: Shaded items are supplemental elements for a system assessment.				Methodology				
System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Baseline compressed airflow supplied to the system. Assess various typical operating periods to annualize the baseline, and establish base-year total compressed air use.	1)	Take measurements to determine the airflow rate supplied to the system, and quantify total compressed air demand (scf) net after all supply side compressed air losses. Record the compressed airflow baseline profile for various typical periods of operation.	na	na	**X**	**X**	**X**

II-3 SUPPLY EFFICIENCY

Quantify and document the overall compressed air supply efficiency, including power (kW/100 scfm) and energy (scf/kWh) efficiency (see also Nonmandatory Appendix A).				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a.	Baseline compressed air supply efficiency. Assess changes in supply side efficiency during normal variations in system compressed airflow profile.	1)	Using supply side power baseline data (Mandatory Appendix II, II-1) and baseline air demand (Mandatory Appendix II, II-2), calculate compressed air supply efficiency, i.e., specific power (kW/100 cfm) and/or energy (scf/kWh). NOTE: Measurement of power and airflow must be independent. Inferred measurement of airflow calculated from direct measurement of power (or vice versa) shall not be used to calculate compressed air supply efficiency.	na	na	**X**	**X**	**X**

II-4 SYSTEM VOLUME

Estimate the total volume of the entire compressed air system. System volume is an important parameter necessary to assess system events and compressor control response. As system pressure increases, compressed air energy is entering storage, and that energy is released from storage as system pressure decreases. There are two methods to determine system volume: mechanical volume and effective volume. Either method may be used (see also para. 6.2).				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a.	Determine the entire volume of the compressed air system.	1)	Determine the mechanical volume of the compressed air system. Review drawings and piping diagrams, and account for existing air receivers and pipelines. Depending on the system size and distribution header diameters and lengths, smaller diameter headers can be omitted.	**X**	na	na	na	na
		2)	Using measured performance data based on field tests or normal load/unload cycling of compressors, calculate the effective volume of the compressed air system.	na	na	**X**	**X**	**X**

II-5 PRESSURE PROFILE

Document the current system pressure profile, and identify opportunities to minimize irrecoverable pressure loss (see also Mandatory Appendix II, II-11, c.1).		Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective	System Assessment Action Item					
	Supply side test pressure points should include compressor discharge, upstream and downstream of supply side treatment equipment, primary storage,					

II-5 PRESSURE PROFILE (Continued)

a.	Baseline the system's present pressure profile. Record system pressure variations and pressure differential between defined test points for various typical periods of operation. Evaluate pressure differential under various normal flow conditions to identify high-pressure drop through excessively restrictive components. Evaluate piping pressure gradient under various normal flow conditions to identify pressure loss during periods of peak air demand and to assess the impact, if any, of high-volume intermittent demand events.	1)	and upstream and downstream of pressure/flow controls.	na	**X**	**X**	**X**	**X**
		2)	Transmission system test pressure points should include entrance to distribution piping, upstream and downstream of treatment equipment, flow pressure controls, and other potential restrictions. Test pressure points should also include remote ends of the distribution piping and, as appropriate, equipment connection point pressure to critical end-use applications.	na	**X**	**X**	**X**	**X**
		3)	Point-of-use test pressure points should include measurement as close as practical to the specific point of use, pressure upstream and downstream of treatment equipment, control valves, piping/tubing, and other potential restrictions.	na	X	X	X	X

II-6 PERCEIVED HIGH-PRESSURE DEMANDS

Assess performance of perceived high-pressure demands, and identify opportunities to reduce system pressure. Identify specific end-use applications to be assessed from those listed in Preliminary Data Collection, Mandatory Appendix I, I-4, d. If no perceived high-pressure demands were identified to receive further, more detailed study, this section does not apply.				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a.	Validate the actual end-use pressure for recommended airflow and pressure requirements.	1)	Refer to equipment documentation, including drawings, installation instructions, operation, and maintenance manuals to determine recommended average and peak airflow rate, along with minimum recommended operating pressure.	**X**	na	na	na	na
b.	Validate the present point-of-use pressure profile from the equipment connection point to the actual end use, including all piping and tubing to the actual end use.	1)	Take measurements to determine pressure profile performance. Test pressure points should include the equipment connection point and measurement as close as practical to the specific point of use. Also, consider pressure measurement upstream and downstream of treatment equipment, control valves, piping/tubing, and other potential restrictions. Record characteristic signatures of the pressure profile. If possible, record pressure data during both normal and abnormal operation of the end-use application.	na	na	**X**	na	**X**
c.	Validate transmission performance, distribution piping, transmission treatment, secondary storage, transmission controls, and piping drops to the equipment connection point.	1)	Take measurements to determine the end-use pressure presently supplied at the equipment connection point to validate the transmission system's support for airflow requirements.	na	na	**X**	na	**X**
d.	Document the end-use minimum, average, and peak airflow rate.	1)	Take measurements to determine airflow rate for the end-use air demand. Assess peak airflow rate as compared with the airflow capacity for point-of-use piping and control components, e.g., filter, regulator, lubricators, shut-off or lock-out valves, control valves, speed controls, etc.	na	na	**X**	na	**X**

II-6 PERCEIVED HIGH-PRESSURE DEMANDS (Continued)

e.	Assess the application and capacity rating of point-of-use treatment equipment to minimize or eliminate irrecoverable pressure loss.	1)	Document end-use requirements for ISO Air Quality Class. Assess point-of-use treatment components, i.e., filters and dryers for appropriate application.	**X**	na	na	na	na
		2)	Take measurements to determine airflow rate for the end-use air demand. Assess peak airflow rate as compared with treatment equipment capacity rating.	na	na	**X**	na	**X**

II-7 DEMAND PROFILE

Quantify and document the present dynamic demand profile, including airflow rate and effectiveness of existing compressed air storage.

Assess the system efficiency and supply side control response.

Assess performance of high-volume intermittent demands. Identify specific end-use applications to be assessed from those listed in Preliminary Data Collection, Mandatory Appendix I, I-4, b.

NOTE: Shaded items are supplemental elements for a system assessment.

	System Assessment Objective		System Assessment Action Item	Methodology: Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Take measurements to determine compressed airflow and pressure dynamics to identify peak, valley, and average airflow rate for various operating time periods.	1)	Take measurements to determine the total dynamic airflow rate of compressed air entering the transmission system.	na	na	**X**	**X**	**X**
		2)	During pressure drawdown, account for airflow entering the system from storage (scfm) based on system capacitance downstream of the flow measurement location (scf/psi) and rate of pressure decay (psi/min).	na	na	**X**	**X**	**X**
		3)	During pressure recovery, account for airflow entering storage (scfm) based on system capacitance (scf/psi) upstream of the flow measurement location and rate of pressure recovery (psi/min).	na	na	**X**	**X**	**X**
b.	Take measurements to determine compressed airflow and pressure dynamics to identify characteristic signatures.	1)	Match characteristic signatures with peak airflow rate, cycle frequency, duration, and dwell time of end-use demands.	na	na	**X**	na	**X**
c.	Quantify selected high-volume intermittent demands: cyclical large air demand for a short time period followed by a dwell time of low or no air demand.	1)	Determine the real dynamic demand requirement, including peak airflow rate, cycle frequency, duration, and dwell time of the high-volume intermittent demand.	na	na	**X**	na	**X**
d.	Take measurements to determine high-volume air demand's impact on system pressure and piping gradient.	1)	Assess the air demand's impact on the system's pressure profile, supply side control response, and impact on system operation and efficiency.	na	na	**X**	**X**	**X**
e.	Evaluate alternative solutions that will control and/or supply the dynamic demand with improved system efficiency.	1)	Gather data necessary to assess storage, pressure/flow control, piping, and pressure profile alternatives to improve overall system performance and efficiency.	na	na	**X**	na	**X**

II-8 CRITICAL AIR DEMANDS

Assess performance of critical air demands and existing poor performing end-use applications.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Document the present pressure performance of critical and poor performing air demands. Assess process-related cause/effect performance relationships and how they impact quality, production rate, scrap rate, rework cost, customer satisfaction, etc.	1)	Investigate how the compressed air system must support the end-use work energy conversion or process related production requirements. Classify the end-use application as a flow static or flow dynamic end use.	na	na	**X**	**X**	**X**
b.	For flow static critical end use and poor performing applications, define the actual required end-use pressure and pressure tolerance necessary for consistent, reliable operation. If possible, assess performance during normal and abnormal operation.	1)	Establish the end-use pressure and allowable variance through measurement and verification of end-use pressure. Test pressure points should include measurement as close as practical to the specific point of use and the equipment connection point pressure to the critical point-of-use application.	na	na	**X**	na	**X**
		2)	Gather data necessary to assess alternative solutions that may be implemented to mitigate documented cause/effect relationships presently resulting in unsatisfactory operation while promoting system efficiency.	**X**	**X**	**X**	**X**	**X**
c.	For flow dynamic critical end use and poorly performing applications, define the actual required end-use dynamic airflow and pressure profile necessary for consistent, reliable operation. Define allowable tolerance for compressed airflow rate and dynamic pressure performance. If possible, assess performance during normal and abnormal operation.	1)	Determine the real dynamic demand requirement, including peak airflow rate and dynamic pressure, that must be sustained during the cycle of the end-use application.	na	na	**X**	na	**X**
		2)	Assess the air demand's impact on the system's pressure profile, supply side control response, and impact on system operation and efficiency.	na	na	**X**	na	**X**
		3)	Gather data necessary to assess application of storage, pressure/flow control, piping, and pressure profile alternatives to improve end-use operation and promote system efficiency.	**X**	**X**	**X**	**X**	**X**
d.	Determine the need to provide process control style monitoring and control of compressed air system performance at critical air demands.	1)	Gather the data necessary to designate process parameters and implement appropriate monitoring and control.	X	X	X	X	X

II-9 IDENTIFY COMPRESSED AIR WASTE

Quantify the energy consumed, and estimate savings opportunities.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective	System Assessment Action Item	Observe — Research	Spot Check	Data Logging	Trending	Dynamics
	Take measurements to determine system or sector air consumption during normal production periods, and compare with minimum production/nonproduction time periods.					

II-9 IDENTIFY COMPRESSED AIR WASTE (Continued)

a.	Identify air wasted to leakage, establish leakage reduction goal, and quantify potential energy reduction.	1)	OR Perform a system bleed down test during minimum production/nonproduction time periods. OR Using other available methods, estimate overall system leakage. THEN Establish a leakage reduction target, and quantify energy savings.	na	**X**	**X**	**X**	na
b.	Assess inappropriate uses, consider alternative energy technologies, and quantify net energy savings. Investigate specific, potentially inappropriate end-use applications as identified in Preliminary Data Collection, Mandatory Appendix I, I-4, c.	1)	Review compressed air demand, and document potentially inappropriate use. Document the justification for continued compressed air use. Or describe application of an alternative energy technology, and quantify net energy reduction.	**X**	**X**	**X**	**X**	**X**
c.	Quantify existing artificial demand as a function of present demand side system or sector pressure and a recommended target pressure.	1)	Take measurements to determine system or sector air consumption and the applied demand side pressure. Establish an appropriate target pressure, and quantify estimated artificial demand reduction and energy savings.	na	na	**X**	**X**	**X**

II-10 OPTIMIZE AIR TREATMENT

Assess and validate the need for, and effectiveness of, treatment equipment as it is presently installed. Identify opportunities for performance improvement and energy reduction. "ISO Class" refers to ISO Standard ISO 8573-1, Compressed air – Contaminates and purity classes. The application of compressed air treatment within a system may be located at the supply side, within the transmission system, and at one or more air demands. Evaluate treatment in all areas.				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a.	Assess end-use applications, and establish air quality ISO Class requirements for the system.	1)	Assess end-use requirements, and document required ISO Class for air treatment. Establish ISO Class for supply side treatment equipment.	**X**	na	na	na	na
		2)	Assess requirements for additional treatment equipment within the transmission system to supply more stringent ISO Class air quality to individual sectors of the system. Document the required ISO Class.	**X**	na	na	na	na
		3)	Identify demands with end-use applications requiring more stringent ISO Class air quality, and document the required ISO Class.	**X**	na	na	na	na
b.	Identify ISO class for air processed though the presently installed air treatment equipment when properly installed and maintained.	1)	Validate the present treatment equipment application and effectiveness as in accordance with ISO 8573-1 Class requirements.	**X**	**X**	**X**	**X**	na
c.	Assess the present performance of air treatment equipment as presently installed and operated.	1)	Investigate treatment equipment-rated performance as related to job site conditions, including airflow rate, inlet temperature, inlet pressure, and ambient temperature, and assess performance.	**X**	**X**	**X**	**X**	na
		2)	Take measurements to determine the pressure dew point at selected air dryers and end-use applications.	na	**X**	**X**	**X**	na

d.	Evaluate air treatment equipment pressure drop for varying airflow rate during low, average, and high demand periods. Document the effect on the system pressure profile.	1)	Take measurements to determine treatment equipment pressure drop during low, average, and high demand periods.	na	**X**	**X**	**X**	na
e.	Assess the dynamic effect of changing airflow rate on the pressure profile.	1)	Take measurements to determine the dynamic response of the system pressure profile associated with typical airflow changes.	na	na	**X**	**X**	**X**
f.	Evaluate intermittent peak airflow rate through treatment equipment, and confirm that it is within rated performance. Also, assess the dynamic effect of intermittent peak airflow rate on the pressure profile.	1)	Take measurements to determine the airflow rate and pressure profile through treatment equipment. Account for the effect of upstream storage volume and drawdown rate to account for storage airflow rate.	na	na	**X**	**X**	**X**
g.	Minimize irrecoverable pressure loss through treatment equipment.	1)	Identify opportunities to reduce or eliminate irrecoverable pressure loss through treatment equipment. Evaluate air treatment alternatives, describe the impact on air quality, and quantify projected energy savings.	X	X	X	X	X

II-11 IMPROVE COMPRESSOR CONTROL

Evaluate the present compressor control strategy and performance response to the existing demand profile. For multiple compressor systems, assess the current method used to coordinate the operation of all compressors. Identify opportunities to improve compressor control, optimize response to the system demand profile, and quantify projected energy reduction.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective		System Assessment Action Item		Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Evaluate the existing compressor control strategy to determine whether it is appropriate for the system demand profile. Using the measurement of compressor power (see Mandatory Appendix II, II-1) and measurement of airflow rate (see Mandatory Appendix II, II-2).	1)	Investigate that compressors are shut down when not required.	**X**	na	**X**	**X**	na
		2)	Assess trim capacity operating strategy, which typically is most efficient with only one air compressor providing trim capacity. Verify that the trim compressor control type provides the best part load operating efficiency for the range of compressor sizes and control types available.	na	na	**X**	**X**	**X**
		3)	Evaluate that base load compressors operate at their most efficient performance condition, typically at full-load design point.	na	na	**X**	**X**	**X**
		4)	Assess the potential for compressors to start in response to intermittent peak demand.	na	na	**X**	X	X
b.	Evaluate the system pressure profile as identified in Mandatory Appendix II, II-4, and assess the potential to optimize compressor control response.	1)	Investigate the minimum and maximum rated working pressure of each air compressor to identify operating limits.	**X**	na	na	na	na
		2)	For each compressor, investigate the compressor profile. Identify the maximum full-flow operating pressure and total package input power. Assess each compressor's performance for part load operation.	**X**	**X**	**X**	**X**	na
c.	Assess the present control signal pressure(s) and compressor control response.	1)	Take measurements to determine the effect of system dynamics on control signal pressure(s) and compressor energy use. Measure pressure according to Mandatory Appendix II, II-5. Determine the magnitude of control pressure shift that occurs with normal airflow variation.	na	**X**	**X**	na	X
		2)	Investigate cause/effect relationships that influence control signal pressure. Identify remedial measures available to improve the control signal pressure and resultant compressor energy response. Quantify projected energy reduction.	na	**X**	**X**	na	**X**

II-12 OPTIMIZE THE SYSTEM PRESSURE PROFILE, AND REDUCE OPERATING PRESSURE

Optimize the system's pressure profile, and assess the opportunity to reduce system pressure. Use information gained in all areas of investigation of the system pressure profile. Include findings from Mandatory Appendices II, II-5 through II-8, II-10, and II-11.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective		System Assessment Action Item		Methodology: Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Optimize the system's pressure profile accounting for end-to-end pressure requirements. Identify the lowest optimum target pressure necessary to reliably support production. Assess the benefit of supplying various demand sectors at different target pressures. Identify demand sectors that should be given priority during unanticipated system draw-down events. Develop robust remedial measures to achieve production reliability and sustainable energy benefits.	1)	Determine the lowest optimum system and or sector pressure for production demands.	X	na	X	X	X
		2)	Establish appropriate target pressure for system or sector supply. Develop the projected system pressure profile after implementation of remedial measures identified in the assessment. Account for all demand side irrecoverable pressure loss associated with transmission and point-of-use losses. Also, account for the necessary recoverable pressure differential associated with demand side secondary storage strategy.	X	na	X	X	X
		3)	Establish the projected supply side pressure profile after implementation of remedial measures identified in the assessment. Account for the necessary compressor control pressure band and irrecoverable pressure loss associated with supply side piping, treatment equipment, etc. Also, account for the necessary recoverable pressure differential associated with application of primary storage strategy.	X	na	X	X	X

II-13 BALANCE SUPPLY AND DEMAND

Using all findings from assessment activity, develop an all-inclusive system control strategy to provide real-time balance between supply and demand. Provide for operating flexibility to efficiently maintain supply-and-demand balance throughout the full range of normal system compressed air demand.

NOTE: Shaded items are supplemental elements for a system assessment.

System Assessment Objective		System Assessment Action Item		Methodology: Observe — Research	Spot Check	Data Logging	Trending	Dynamics
a.	Quantify the mismatch between rotating generation capacity and system demand. Investigate the opportunity to automate shutdown of unneeded compressor capacity.	1)	Compare rotating generation capacity power measured (Mandatory Appendix II, II-1) with compressed air demand (Mandatory Appendix II, II-2), and quantify excess generation.	X	na	X	X	na
		2)	To allow automatic shutdown of compressors, investigate the amount of useable air in storage that is necessary to support permissive start time for automatic start-up of compressors.	X	na	X	X	na
		3)	Determine whether additional storage is required; calculate the recommended size and pressure differential.	X	na	X	X	X

b.	Delay or prevent start-up of compressors in response to short duration demand events.	1)	Assess the availability of storage to support demand events, including peak airflow rate, cycle frequency, duration, and dwell time of the demand event (see also Mandatory Appendix II, II-7, c.).	**X**	na	**X**	**X**	na
c.	Investigate alternative system control strategies combining storage, compressor control, and automation to create and maintain alignment between supply and demand.	1)	Given the present mix of compressor sizes, control types, and available storage, optimize supply-and-demand balance.	**X**	na	**X**	**X**	**X**
		2)	Optimize primary and secondary storage to maintain dynamic balance between supply and demand. Optimize compressor control to replenish storage.	**X**	na	**X**	**X**	**X**
		3)	Investigate the application of alternative compressor sizes and control types to optimize supply efficiency.	**X**	na	**X**	**X**	na
		4)	Investigate the role of automation in control of multiple compressors.	**X**	na	**X**	**X**	**X**
		5)	Identify remedial measures necessary to optimize supply-and-demand balance, storage strategy, compressor control response, and automation of multiple compressor control. Quantify projected energy reduction.	**X**	na	**X**	**X**	X

II-14 ASSESS MAINTENANCE OPPORTUNITIES

Evaluate maintenance performed and its impact on energy efficiency, performance, and reliability of compressed air system equipment. Evaluate interaction with other systems, such as heating, ventilation, and air conditioning (HVAC) equipment performance and energy use. Investigate opportunities to improve performance and reliability while reducing total energy use. Recommend specific remedial measures, and estimate energy reduction and savings.				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a	Evaluate compressor intake conditions.	1)	Assess compressor intake conditions, including, filter pressure drop, intake location, and frictional loss for intake piping.	**X**	**X**	**X**	na	na
		2)	Evaluate ambient conditions and suitability of the present intake filter, given the particle size and amount of contamination present at the intake location.	**X**	**X**	na	na	na
		3)	Estimate the effect of current intake conditions on delivered compressor capacity, reliability, and energy efficiency.	X	X	**X**	**X**	na
		4)	Investigate specific recommendations to improve compressor intake conditions and estimated performance improvement and energy reduction.	**X**	**X**	na	na	na
b.	Investigate the present installation and maintenance of condensate traps; they should reliably remove condensate, but not compressed air, and should not be left open.	1)	Inventory and classify existing drains: manual, float style, solenoid timer, and zero-air loss with reservoirs.	**X**	**X**	na	na	na
		2)	Assess the performance and maintenance associated with existing condensate drains. Assess present performance for proper operation, failure to remove condensate, and excessive air waste. Estimate the present air waste, energy loss, and cost associated with improper operation of condensate drains.	**X**	**X**	na	na	na
		3)	Recommend remedial measures for routine trap functional checks, maintenance, and replacement. Quantify estimated energy reduction.	**X**	**X**	na	na	na

II-14 ASSESS MAINTENANCE OPPORTUNITIES (Continued)

c.	Compressor cooling.	1)	Check compressor operating temperature, assessing the performance of the oil-cooler, inter-stage coolers, and compressed air after-cooler. Compare temperature measurements with the manufacturer's recommended operating temperatures and maximum temperature limits.	**X**	**X**	na	na	na
d.	Air-cooled compressor's cooling airflow and performance.	1)	For air-cooled compressors, assess the cooling air temperature and airflow through the air-cooled coolers. If external duct work has been attached, evaluate the static pressure loss through duct work as compared with the manufacturer's recommended maximum external static pressure. Investigate the installation and operation of booster fans or blowers to aid in ventilation airflow.	**X**	**X**	na	na	na
e.	Water-cooled compressor's cooling water conditions and water flow.	1)	For water-cooled compressors, assess the cooling water temperature entering the compressor and temperature rise to the water discharge connection. Measure water inlet pressure, and assess the suitability of water drains. If a tower water or other closed loop system is used, measure the return header pressure at the compressor's water discharge, and compare with the manufacturer's recommended water pressure differential.	X	X	na	na	na
f.	Compressor room ventilation.	1)	Check for proper airflow patterns to prevent heat from one piece of equipment affecting the cooling of other equipment.	**X**	**X**	na	na	na
		2)	Check for adequate exhaust ventilation and sufficient make-up air to prevent negative pressure from occurring in the compressor room.	**X**	**X**	na	na	na
		3)	Assess the impact of compressor cooling on heating, ventilation, and air conditioning (HVAC) equipment energy use. If the air compressors add heating or cooling energy load on HVAC equipment, assess alternatives that will have lesser impact on HVAC equipment energy use.	**X**	**X**	na	na	na
g.	Compressed air treatment equipment temperatures.	1)	Measure temperatures associated with operation of treatment equipment. Compare actual operating temperature with the manufacturer's specifications. Ensure that equipment is operating within specified limits or performance capacity has been properly rerated for job site conditions.	**X**	**X**	na	na	na
		2)	If indicated, recommend remedial measures for proper treatment of compressed air, and quantify estimated energy and cost reduction (see also Mandatory Appendix II, II-10).	X	X	na	na	na

II-15 HEAT RECOVERY

Investigate the potential to use heat rejection from the air compressors to offset existing energy use.				Methodology				
NOTE: Shaded items are supplemental elements for a system assessment.				Observe — Research	Spot Check	Data Logging	Trending	Dynamics
System Assessment Objective		System Assessment Action Item						
a.	Determine the amount of heat rejection from the air compressors. Identify other potential heat sources that may be combined with the air compressors to increase the total amount of available heat. Investigate existing energy users and the amount of recoverable heat that can be applied. Estimate the total net amount of recovered energy, existing energy offset, and annualize savings.	1)	Assess the compressor's cooling system and manufacturer's specifications for heat rejection: cooling air/water flow, rate of heat rejection, and temperature.	X	na	na	Na	na
		2)	Investigate existing heating applications with the potential to use heat rejection from the compressor to offset existing energy use.	X	X	X	X	na
		3)	Estimate the amount of recoverable heat. Provide for suitable heat rejection to maintain reliable compressor operation when the recoverable heat load is reduced or off-line.	X	na	na	Na	na
		4)	Annualize the net energy reduction, and estimate savings.	X	na	na	Na	na

NONMANDATORY APPENDIX A
UNITS OF MEASURE FOR COMPRESSED AIR SYSTEM ASSESSMENT

The following are units of measure for compressed air system assessment:

(a) Pressure Units of Measure. Pounds per square inch gage (psig) [bar or kilopascal (kPa) gage].

(b) Production Output Units of Measure. Production output should be quantified using the plant's routine measure of production output, e.g., number of units or tons of product.

Table A-1 Compressed Air and Primary Energy Resource Units of Measure

Parameter	Power: Time Rate Measurement	Energy: Total Measurement
Compressed airflow	standard cubic feet per minute (scfm) [normal cubic meters per minute (Nm^3/m)] Compressed airflow rate shall be quantified as mass flow. Common measures of mass flow are pounds mass, standard cubic feet, and normal cubic meters per unit of time (typically minutes or seconds). Volumetric measures should not be used.	standard cubic feet (scf) [normal cubic meters (Nm^3)] or million standard cubic feet (MMscf) Total amount compressed air shall be quantified as pounds mass, standard cubic feet, kilograms, or other unit of mass; volumetric measures should not be used.
Primary energy resource	kilowatt (kW) The primary energy resource shall be quantified in units of power (e.g., watt, Btu/min, calorie/sec).	kilowatt-hour (kWh) or gigawatt-hour (GWh) The primary energy resource total consumption shall be quantified in units of energy (e.g., watt, joule, Btu).
Compressed air supply efficiency	kilowatts per 100 standard cubic feet per minute (kW/100 scfm) or standard cubic feet per minute per kilowatt (scf m/kW) [normal cubic meters per minute per kilowatt (Nm^3/kW)] The compressed airflow rate shall be net mass flow of compressed air after all parasitic mass flow losses, e.g., supply leakage, air dryer purge air use, etc. The primary energy resource rate of consumption shall include all energy input associated with compressed air supply (e.g., air compressors, dryers, pumps, fans).	kilowatt-hour per standard cubic foot (kWh/scf) [kilowatt-hours per normal cubic meter (kWh/Nm^3)] or standard cubic feet per kilowatt-hour (scf/kWh) [normal cubic meters per kilowatt-hour (Nm^3/kWh)] The compressed airflow rate shall be total net mass of compressed air after all parasitic mass flow losses; e.g., supply leakage, air dryer purge air use, etc. The primary energy resource shall be total net energy used, including all energy input associated with compressed air supply (e.g., air compressors, dryers, pumps, fans).

A-1 UNITS OF MEASURE USED FOR REFERENCE PURPOSES

For the purpose of this Standard, units of measure as listed below will be used for reference. The practitioner may use any appropriate unit of measure.

(a) Compressed Airflow Rate. (time rate measurement of compressed airflow) standard cubic feet per minute (scfm).

(b) Compressed Air Total. (total measurement of compressed air) standard cubic feet (scf) and million standard cubic feet (MMscf).

(c) Electrical Power. (time rate measurement of primary energy resource) kilowatt (kW).

(d) Electrical Energy. (total measurement of primary energy resource) kilowatt-hour (kWh).

(e) Power Supply Efficiency. (time rate measurement of compressed air supply efficiency) kilowatt per 100 standard cubic feet per minute (kW/100 scfm).

(f) Energy Supply Efficiency. (total measurement of compressed air supply efficiency) standard cubic feet per kilowatt-hour (scf/kWh).

A-2 NOTES — UNITS OF MEASURE REFERENCE

For compressed air mass flow rate term (scfm), standard conditions are defined as 14.5 psia, 68°F, and 0% RH.

The total measurement of compressed air supply efficiency energy term (scf/kWh) with standard conditions is defined above.

A traditional unit of measure used for time rate measurement of compressed air supply efficiency is scfm/kW.

The time rate measurement of compressed air supply efficiency (kW/100 scfm) referenced here is supplied in volumetric terms (kW/100 cfm) by CAGI member companies that have developed standard performance reporting data sheets[1] for compressed air supply equipment. The air compressor performance data sheets include specific package input power at rated capacity and full-load operating pressure given in units of kW/100 cfm. Note the airflow rate cfm given in volumetric terms (cfm) can be corrected to mass flow (scfm) for the atmospheric pressure, temperature, and relative humidity conditions as they exist at the compressor installation site.

[1] For additional information on CAGI data sheets and performance verification program, visit the Compressed Air and Gas Institute Web site at http://www.cagi.org/verification/ea_sheets.htm.

NONMANDATORY APPENDIX B
KEY REFERENCES

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