[6450-01-P]

DEPARTMENT OF ENERGY

10 CFR Parts 429 and 431

[Docket No. EERE-2014-BT-TP-0054]

RIN 1904-AD43

Energy Conservation Program: Test Procedures for Compressors

AGENCY: Office of Energy Efficiency and Renewable Energy, Department of Energy.

ACTION: Notice of proposed rulemaking and announcement of public meeting.

SUMMARY: In this document, the U.S. Department of Energy (DOE) proposes to prescribe new definitions, sampling provisions, and test procedures for compressors in a new subpart of DOE regulations. The proposed test procedure would provide instructions for determining the full-load package isentropic efficiency for certain fixed-speed compressors and the part-load package isentropic efficiency for certain variable-speed compressors based on test methods described in International Organization for Standardization (ISO) Standard 1217:2009, “Displacement compressors – Acceptance tests,” (ISO 1217:2009). This document also proposes certain modifications and additions to ISO 1217:2009 to increase the specificity of certain testing methods and improve the repeatability of tested and measured values. In this notice, DOE also announces a public meeting to discuss and receive comments on issues presented in this notice of proposed rulemaking.

DATES: Comments: DOE will accept comments, data, and information regarding this notice of proposed rulemaking (NOPR) before and after the public meeting, but no later than **[INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER PUBLICATION]**. See section V, "Public Participation," for details.

Meeting: DOE will hold a public meeting on Monday, June 20, 2016 from 9:30 a.m. to 12:00 p.m. in Washington, DC. The meeting will also be broadcast as a webinar. See section V, "Public Participation," for webinar registration information, participant instructions, and information about the capabilities available to webinar participants.

ADDRESSES: The public meeting will be held at the U.S. Department of Energy, Forrestal Building, Room 8E-089, 1000 Independence Avenue, SW., Washington, DC 20585. Persons may also attend the public meeting via webinar. To attend, please notify Ms. Brenda Edwards at (202) 586-2945. For more information, refer to section V, "Public Participation," near the end of this document.

Interested parties are encouraged to submit comments using the Federal eRulemaking Portal at www.regulations.gov. Any comments submitted must identify the NOPR for test procedures for compressors, and provide docket number EERE–2014–BT–TP–0054 and/or regulation identifier number (RIN) 1904–AD43. Comments may be submitted using any of the following methods:

- Federal eRulemaking Portal: www.regulations.gov. Follow the instructions for submitting comments.
- E-mail: AirCompressors2014TP0054@ee.doe.gov Include the docket number and/or RIN in the subject line of the message.
- Mail: Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, Mailstop EE-5B, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. If possible, please submit all items on a compact disk (CD), in which case it is not necessary to include printed copies.
- Hand Delivery/Courier: Ms. Brenda Edwards, U.S. Department of Energy, Building Technologies Office, 950 L'Enfant Plaza, SW., Suite 600, Washington, DC, 20024. Telephone: (202) 586-2945. If possible, please submit all items on a CD, in which case it is not necessary to include printed copies.

No telefacsimiles (faxes) will be accepted. For detailed instructions on submitting comments and additional information on the rulemaking process, see section V of this document (Public Participation).

DOCKET: The docket, which includes Federal Register notices, public meeting attendee lists and transcripts, comments, and other supporting documents/materials, is available for review at www.regulations.gov. All documents in the docket are listed in the regulations.gov index. However, some documents listed in the index, such as those containing information that is exempt from public disclosure, may not be publicly available.

A link to the docket web page can be found at: https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/87. This web page will contain a link to the docket for this proposed rule on the www.regulations.gov site. The www.regulations.gov web page will contain simple instructions on how to access all documents, including public comments, in the docket. See section V for information about how to submit comments through regulations.gov.

FOR FURTHER INFORMATION CONTACT:

Mr. James Raba, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Office, EE–5B, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 586-8654. E-mail: compressors@ee.doe.gov.

Ms. Johanna Jochum, U.S. Department of Energy, Office of the General Counsel, GC–33, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 287-6307. E-mail: Johanna.Hariharan@hq.doe.gov.

For further information on how to submit a comment, review other public comments and the docket, or participate in the public meeting, contact Ms. Brenda Edwards at (202) 586-2945 or by email: Brenda.Edwards@ee.doe.gov.

SUPPLEMENTARY INFORMATION:

DOE proposes to incorporate by reference into part 431 the testing methods contained in certain applicable sections of the following industry standard:

International Organization for Standardization (ISO) 1217:2009, "Displacement compressors – Acceptance tests," sections 2, 3, and 4; subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), 6.2(h); and subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C.

This material is available from the International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org. +41 22 749 01 11. It is also available for inspection at U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, Suite 600, 950 L'Enfant Plaza, SW., Washington, DC 20024, (202) 586-2945, or go to http://energy.gov/eere/buildings/appliance-and-equipment-standards-program.

See section IV.M for additional information on this standard.

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I. Authority and Background

Compressors are included in the list of "industrial equipment" that DOE may determine to include as "covered equipment," and thus establish and amend energy conservation standards and test procedures. (42 U.S.C. 6311(1)(L), 6311(2)(A)-(B), 6312(b)). Specifically, DOE issued a Proposed Determination of Coverage (2012 Proposed Determination) that proposed to establish compressors as covered equipment. 77 FR 76972 (Dec. 31, 2012). However, DOE has not yet exercised this authority and thus no Federal energy conservation standards or test procedures for compressors are currently in place. In this document, DOE proposes to establish test procedures for compressors. The following sections discuss DOE's authority to establish test procedures for compressors and relevant background information regarding DOE's consideration of test procedures for this equipment.

A. Authority

Title III of the Energy Policy and Conservation Act of 1975, as amended, (42 U.S.C. 6291, et seq.; "EPCA" or, "the Act") sets forth a variety of provisions designed to improve energy efficiency.[1]

Part C of Title III, which for editorial reasons was codified as Part A-1 upon incorporation into the U.S. Code (42 U.S.C. 6311–6317), establishes the Energy Conservation Program for Certain Industrial Equipment. Under EPCA, DOE may include a type of industrial equipment, including compressors, as covered equipment if it determines that to do so is necessary to carry out the purposes of Part A-1. (42 U.S. 6311(1)(L), 6311(2)(B)(i), and 6312(b)). The purpose of Part A-1 is to improve the efficiency of electric motors and pumps and certain other industrial equipment in order to conserve the energy resources of the Nation. (42 U.S.C 6312(a)) In DOE's 2012 Proposed Determination, DOE proposed to determine that because (1) DOE may only prescribe energy conservation standards for covered equipment; and (2) energy conservation standards for compressors would improve the efficiency of such equipment more than would be likely to occur in the absence of standards, including compressors as covered equipment is necessary to carry out the purposes of Part A-1. 77 FR 76972 (Dec. 31, 2012).

[1] All references to EPCA in this document refer to the statute as amended through the Energy Efficiency Improvement Act of 2015, Public Law 114-11 (Apr. 30, 2015).

Pursuant to EPCA, DOE's energy conservation program for covered equipment consists essentially of four parts: (1) testing; (2) labeling; (3) Federal energy conservation standards; and (4) certification and enforcement procedures. Specifically, subject to certain criteria and conditions, EPCA requires DOE to develop test procedures to measure the energy efficiency, energy use, or estimated annual operating cost of each type of covered equipment. (42 U.S.C. 6316(a)) Manufacturers of covered equipment must use the prescribed DOE test procedure: (1) as the basis for certifying to DOE that their equipment complies with the applicable energy conservation standards adopted under EPCA (42 U.S.C. 6295(s) and 6316(a)) and (2) when making representations to the public regarding the energy use or efficiency of those equipment. (42 U.S.C. 6314(d)) Similarly, DOE must use these test procedures to determine whether the equipment complies with any relevant standards adopted pursuant to EPCA. (42 U.S.C. 6295(s) and 6316(a))

There are currently no DOE test procedures or energy conservation standards for compressors. However, DOE is currently evaluating whether to establish energy conservation standards for certain categories of compressors. (Docket No. EERE-2014-BT-STD-0040) DOE must first establish a test procedure that measures the energy use, energy efficiency, or estimated operating costs of such equipment, prior to establishing energy conservation standards for such equipment. See generally 42 U.S.C. 6295(r) and 6316(a).

EPCA sets forth the criteria and procedures DOE is required to follow when prescribing or amending test procedures for covered equipment. (42 U.S.C. 6314)

Among other things, EPCA requires that test procedures must be reasonably designed to produce test results which reflect energy efficiency, energy use, and estimated operating costs of a type of industrial equipment (or class thereof) during a representative average use cycle (as determined by the Secretary of Energy), and shall not be unduly burdensome to conduct. (42 U.S.C. 6314(a)(2)) Furthermore, DOE is required to publish the proposed test procedures in the Federal Register, and afford interested persons an opportunity (of not less than 45 days' duration) to present oral and written data, views, and arguments on the proposed test procedures. (42 U.S.C. 6314(b))

Consistent with EPCA requirements, DOE proposes to prescribe a test procedure for certain categories of compressors to be used with its ongoing energy conservation standards rulemaking for this equipment (Docket No. EERE-2013-BT-STD-0040). The test procedure, if adopted, would include the methods necessary to: (1) measure certain performance parameters of the compressor (i.e., inlet and discharge pressures, flow rate, and packaged compressor power input); and (2) use the measured results to calculate the package isentropic efficiency[2] of the compressor, inclusive of all compressor-package components. DOE proposes specific test procedures and metrics for fixed-speed versus variable-speed compressors: full-load efficiency for fixed-speed compressors and a part-load efficiency for variable-speed compressors. DOE also proposes to establish the categories of compressors to which the proposed test method would apply.

[2] Package isentropic efficiency is defined as the ratio of power required for an ideal isentropic compression process to the actual packaged compressor power input used at a given load point, as determined in accordance with the methods described in sections 0 and 0.

If DOE adopts an applicable test procedure, manufacturers would be required to use the adopted test procedure and performance metrics when making representations regarding the energy consumption of covered equipment beginning 180 days after publication of the test procedure final rule in the Federal Register (42 U.S.C. 6314(d)) (see section III.F).

B. Background

Consistent with DOE's authority under EPCA, as discussed in section I.A, DOE issued the 2012 Proposed Determination that proposed to establish compressors as covered equipment. 77 FR 76972 (Dec. 31, 2012). Subsequently, in February 2014, DOE published a Notice of Public Meeting and Availability of the Framework Document to initiate an energy conservation standard rulemaking for compressors. 79 FR 6839 (Feb. 5, 2014). In the Framework Document, DOE requested feedback from interested parties on multiple issues, including the definition of compressor, characteristics of different compressor categories, and how to test compressor efficiency. DOE held a public meeting to discuss the Framework Document on April 1, 2014, hereafter referred to as the "Framework public meeting." DOE received 15 comments in response to the Framework Document. After the comment period, DOE held interviews with several interested parties to help gather additional information necessary to complete the regulatory analyses that were described in the Framework Document. Those recommendations received from interested parties in both comments on the Framework Document and during the Framework public meeting, as well as feedback provided during the preliminary manufacturer interviews, that are pertinent to the test procedure and performance metric are addressed in this NOPR and reflected in DOE's proposed compressor test procedure.

II. Summary of the Notice of Proposed Rulemaking

In this test procedure NOPR, DOE proposes to establish a new subpart T to 10 CFR part 431 that would contain, among other things, definitions and a test procedure applicable to compressors. However, DOE proposes to establish test procedures for only a specific subset of compressors. Specifically, this proposed test procedure would apply only to a subset of rotary and reciprocating compressors, as defined in section III.B of this NOPR. DOE intends this proposed test procedure to apply to the same equipment for which DOE is considering adopting energy conservation standards (Docket No. EERE-2014-BT-TP-0054). However, DOE notes that the scope of any energy conservation standards would be established in that rulemaking.

This proposed test procedure prescribes methods for measuring and calculating the energy performance of certain rotary and reciprocating compressors, inclusive of all compressor package components.[3] DOE also proposes to describe the energy performance of certain rotary and reciprocating compressors using package isentropic efficiency. The package isentropic efficiency describes the ratio of the ideal isentropic power required for compression to the actual packaged compressor power input used for the same compression process. DOE proposes to use full-load package isentropic

[3] As discussed further in section III.B.2.c, DOE proposes to define air compressors as a "packaged compressor," inclusive of a compression element ("bare compressor"), driver(s), and mechanical equipment to drive the compressor element.

efficiency as the metric for rating certain fixed-speed compressors ($\eta_{isen,FL}$) and part-load package isentropic efficiency as the metric for rating certain variable-speed compressors ($\eta_{isen,PL}$). DOE believes these metrics would provide a representative measurement of the energy performance of the rated compressor under an average cycle of use.

DOE's proposed test method includes measurements of the inlet and discharge pressures, actual volume flow rate, and packaged compressor power input, as well as calculations of the theoretical power necessary for compression – all of which are required to calculate full- or part-load package isentropic efficiency. For reproducible and uniform measurement of these values, DOE proposes to incorporate by reference the test methods established in certain applicable sections of ISO Standard 1217:2009, "Displacement compressors – Acceptance tests," sections 2, 3, and 4; subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), 6.2(h); and subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C; along with certain modifications and additions, as noted in section III.D.2. Members of the compressor industry developed ISO 1217:2009, which contains methods for determining inlet and discharge pressures, actual volume flow rate, and packaged compressor power input for electrically driven packaged displacement compressors. DOE has reviewed the relevant sections of ISO 1217:2009 and has determined that ISO 1217:2009, in conjunction with the additional referenced test methods and calculations proposed in this test procedure (see sections III.D.2 and III.C, respectively), would produce test results that reflect the energy efficiency, energy use, or estimated operating costs of a compressor during a representative average use cycle. (42 U.S.C. 6314(a)(2)) DOE has also reviewed the burdens associated with conducting the proposed test procedure, including ISO 1217:2009 and, based on the results of such analysis, has found that the proposed test procedure would not be unduly burdensome to conduct. (See 42 U.S.C. 6314(a)(2)) DOE's analysis of the burdens associated with the proposed test procedure is presented in section IV.B.

DOE also proposes to establish, in subpart B of part 429 of Title 10 of the Code of Federal Regulations, requirements regarding the sampling plan for testing and allowable representations for certain rotary and reciprocating compressors. The proposed sampling plan requirements are similar to those for several other types of commercial and industrial equipment (e.g., pumps) and are appropriate for compressors based on the expected range of measurement uncertainty and manufacturing tolerances for this equipment (see section III.G). DOE also proposes provisions regarding the representations of energy consumption, energy efficiency, and other relevant metrics manufacturers may make in their manufacturer literature (see section III.F). Any representations of the energy efficiency or energy use of compressors to which an adopted test procedure applies must be made based on the adopted compressor test procedure beginning 180 days after the publication date of any test procedure final rule establishing such procedures. (42 U.S.C. 6314(d))

III. Discussion

In this NOPR, DOE proposes to place a new compressor test procedure and related definitions into a new subpart T of part 431, add new sampling plans for this equipment in a new section 429.61 of 10 CFR part 429, add a new alternative efficiency determination method (AEDM) for this equipment in 10 CFR 429.70, and add new enforcement provisions for compressors in 10 CFR 429.110 and 134. The proposed subpart T would contain definitions, materials incorporated by reference, and the test procedure applicable to certain classes and configurations of compressors established as a result of this rulemaking, as shown in Table III.1. DOE would also incorporate in subpart T any energy conservation standards for compressors resulting from the concurrent energy conservation standard rulemaking. (See Docket No. EERE-2013-BT-STD-0040)

Table III.1 Summary of Proposals in this NOPR, their Location within the Code of Federal Regulations, and the Applicable Preamble Discussion

Location	Proposal	Summary of Additions	Applicable Preamble Discussion
10 CFR 429.61*	Sampling Plan	Minimum number of compressors to be tested to rate a compressor basic model	Section III.G
10 CFR 429.110	Enforcement Provisions	Method for determining compliance of basic models	Section III.G.3
10 CFR 431.341	Purpose and Scope	Scope of the proposed compressor regulations	Section III.B
10 CFR 431.342	Definitions	Definitions pertinent to categorizing and testing of compressors	Section III.B.2
10 CFR 431.343	Incorporation by Reference	Description of industry standards incorporated by reference in the DOE test procedure and related definitions	Section III.D
10 CFR 431.344	Test Procedure	Instructions for determining the package isentropic efficiency for applicable categories of compressors	Sections III.C and III.D

* Note: DOE also proposes minor modifications to 10 CFR 429.2 and 429.70; to apply the general definitions to the equipment-specific provisions proposed for compressors at 10 CFR 429.61 and propose AEDM requirements for compressors, respectively.

The following sections discuss DOE's proposals regarding establishing new testing and sampling requirements for compressors, including A) definition of covered equipment, B) scope of applicability of the test procedure, C) energy-related metrics, D) test method, E) definition of basic model, F) representations of energy use and energy efficiency, and G) sampling plans for testing and AEDMs.

These sections also present any pertinent comments DOE received in response to the February 2014 Framework Document, as well as DOE's responses to those comments.

A. Definition of Covered Equipment

Although a compressor is listed as a type of industrial equipment in EPCA, the term is not defined. (42 U.S.C. 6311(2)(B)(i)) In the Framework Document, DOE requested feedback on a definition for the term "compressor," taken from the International Organization for Standardization (ISO) Technical Report 12942:2012, "Compressors – Classification – Complementary information to ISO 5390," ("ISO/TR 12942:2012"). (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 3). Specifically, ISO Technical Report 12942:2012 defines compressor as a machine or apparatus converting different types of energy into the potential energy of gas pressure for displacement and compression of gaseous media to any higher pressure values above atmospheric pressure with pressure-increase ratios exceeding 1.1.

In response to the provided definition, the Edison Electric Institute (EEI) supported the use of the ISO/TR 12942:2012 definition. The National Resources Defense Council (NRDC), the Northwest Energy Efficiency Alliance (NEEA), the California Investor Owned Utilities (CA IOUs), the Southern California Gas Company (SCGC), and a joint comment submitted by the American Council for an Energy-Efficiency Economy (ACEEE), the Appliance Standards Awareness Project (APSP), the Northwest Energy Efficiency Alliance (NEEA), and the Alliance to Save Energy (ASE) (hereafter referred to as the Joint Commenters) recommended establishing the pressure ratio that defines compressors to align with the maximum ratio that will eventually be proposed for the DOE's energy conservation standards rulemaking for fans and blowers ("Fans and Blowers Rule," Docket No. EERE-2013-BT-STD-0006, EEI, No. 0012 at p. 3; NRDC, No. 0019 at p. 1; NEEA, No. 0040 at p. 23; CA IOUs, No. 0018 at p. 2; SCGC, No. 0018 at p. 2; and Joint Comment, No. 0016 at p. 1) The Compressed Air and Gas Institute (CAGI) commented that the pressure ratio was too low and suggested using a ratio of 2.5. (CAGI, No. 0009 at p. 1; CAGI, No. 0040 at p.2)

DOE agrees with the recommendations from interested parties suggesting alignment of the pressure ratio used to define compressors with any maximum pressure ratio adopted for fans and blowers. That is, DOE believes that, in order to ensure comprehensive and equitable coverage of equipment (i.e., prevent gaps in coverage and double coverage by two rules) it is critical that the maximum pressure ratio applicable to fans and blowers be mutually exclusive with the minimum pressure ratio proposed to define compressors.

Although DOE intends to align the maximum pressure ratio for fans and blowers with the minimum pressure ratio for compressors, DOE notes that the Fans and Blowers Rules are currently in progress and that DOE has not issued a notice of proposed rulemaking for either a test procedure or energy conservation standards. As a result, DOE has not yet offered any formal proposals for a limiting maximum pressure ratio for fans and blowers.

However, DOE discussed the use of pressure ratio limits in the Framework Document for its Fans and Blowers Rule. Specifically, DOE discussed a definition for the term "blower," as "an axial or centrifugal fan with a "specific ratio,[4]" between 1.11 and 1.20" (Docket No. EERE-2013-BT-STD-0006-0001 at p. 9).

DOE received comments in response to its discussion of specific ratio limits in the Fans and Blowers Rule Framework Document. Specifically, Ingersoll-Rand supported use of an upper limit of 25 kJ/kg for equipment being considered as a part of the Fans and Blowers Rule (Docket No. EERE-2013-BT-STD-0006-0153 at p. 6). DOE notes that ISO 13349:2010[5] also defines fans based on a maximum energy limit of 25 kJ/kg of air and indicates that 25 kJ/kg is equivalent to a specific ratio of 1.3. The CA IOUs, in response to the Fans and Blowers Framework Document, commented that they were aware of the ongoing compressors rulemaking, and that the respective pressure ratio limits of each rule should be aligned in order to prevent gaps in coverage ("Fans and Blowers Rule," Docket No. EERE-2013-BT-STD-0006-0011 at p. 3).

Additionally, DOE notes that, following the completion of the Framework comment period, an ASRAC Working Group was established to negotiate proposed energy conservation standards for fans and blowers. 80 FR 17359 (Apr. 1, 2015). Ultimately this Working Group concluded its negotiations on September 3, 2015, with a supportive vote on several recommendations ("a term sheet") for DOE regarding the

[4] Specific ratio is defined in ISO 13349:2010 as the total pressure at the outlet of the fan over the total inlet pressure. This term is synonymous to pressure ratio, as discussed in this document.

[5] ISO 13349:2010 Fans — Vocabulary and definitions of categories

testing and regulation this equipment. (Docket No. EERE-2013-BT-STD-0006, No. 179) Although the Working Group's term sheet did not explicitly include an upper limit on pressure ratio, the working group did discuss, and come to "general agreement" on a "maximum fan energy limit of 25 kJ/kg" (approximately 1.3 pressure ratio) as the appropriate cutoff to distinguish between fans and compressors. (Docket No. EERE-2013-BT-STD-0006; Public Meeting, No. 84 at p. 11).

As discussed previously, DOE agrees with the recommendations from NRDC, NEEA, CA IOUs, SCGC and the Joint Commenters, suggesting alignment of the pressure ratio used to define compressors with any maximum pressure ratio adopted for fans and blowers. Consequently, DOE proposes to incorporate into its definition of a compressor, a pressure ratio limit of greater than 1.3. DOE believes that, based on the most recent Fans and Blowers Rule public information (discussed above), a pressure ratio limit of 1.3 is the most appropriate cutoff to distinguish between fans and compressors, and this cutoff limit meets the intent of definitional alignment between the Fans and Blowers Rule and this rulemaking.

DOE notes that it is proposing to limit the definition of a compressor using pressure ratio, rather than fan energy (in kJ/kg), as fan energy is not a commonly used parameter in the compressor industry and DOE is unaware of any compressor industry test standards that specify the calculation of such a parameter. Alternatively, pressure ratio is a commonly used, and well understood, parameter in the compressor industry, and is easily derived from test methods contained in common industry standards, such as ISO 1217:2009.

In addition to the lower pressure ratio limit of "greater than 1.3", DOE proposes to base the remainder of its compressor definition on the ISO 12942:2012 definition of a compressor; which was discussed in the Compressors Framework Document and supported in previously discussed comments submitted by EEI.

Ultimately, DOE proposes to define a compressor as a machine or apparatus that converts different types of energy into the potential energy of gas pressure for displacement and compression of gaseous media to any higher pressure values above atmospheric pressure and has a pressure ratio[6] greater than 1.3.

DOE notes that proposing a pressure ratio of greater than 1.3, DOE intends to align the minimum pressure ratio for compressors to the maximum ratio proposed in the fans and blowers rule and create a continuous spectrum of coverage between the two equipment types. However, as discussed previously, the fans and blowers rulemaking is still in progress, and the limit of 25 kJ/kg (approximately a 1.3 pressure ratio) discussed during Working Group negotiations has not been proposed by DOE and is subject to change. As such, DOE reiterates that the primary intent of proposing a pressure ratio greater than 1.3 is to align with the fans and blowers rule and creates a continuous spectrum of coverage between the two equipment types. If the fans and blowers rulemaking ultimately proposes and adopts an upper limit other than 25 kJ/kg, DOE may alter the pressure ratio threshold of greater than 1.3 referenced in the compressor

[6] DOE proposes to use terminology consistent with ISO 1217:2009 in describing the ratio of discharge to inlet pressures as "pressure ratio," as opposed to "pressure-increase ratio," which is the term used in some other industry documents. However, for the purpose of this document "pressure-increase ratio" and "pressure ratio" are synonymous.

definition, in order to achieve the original intent of this proposal, either through this rulemaking, the fan and blowers rulemaking, or other subsequent rulemakings.

In order to objectively and unambiguously determine whether equipment meets the definition of compressor, DOE also proposes to define the term "pressure ratio." DOE proposes to define pressure ratio as the ratio of discharge pressure to inlet pressure, as determined at full-load operating pressure. This definition allows DOE to establish quantitatively which equipment meet the pressure ratio requirement proposed in the definition of compressor.

This definition of pressure ratio relies on the terms discharge pressure and inlet pressure. Definitions and methods to calculate the discharge pressure and inlet pressure are established in ISO 1217:2009, certain sections of which DOE proposes to incorporate by reference (see section III.D). DOE also notes that in this NOPR DOE proposes methods to identify full-load operating pressure; such methods are discussed further in section III.D.2.i.

DOE requests comment on the proposed definitions for compressor and pressure ratio, as well as the definitions referenced in ISO 1217:2009.

DOE requests comment on the proposed lower limit of pressure ratio for compressors of "greater than 1.3."

B. Scope of Applicability of the Test Procedure

1. Summary of Scope of Applicability

DOE notes that while the definition of compressor, as proposed in section III.A, is broad, the categories of compressors to which the proposed test procedure applies would be limited to a more narrow range of equipment. Specifically, after consideration of feedback from interested parties, as well as DOE research, DOE proposes to limit the applicability of this test procedure to compressors that meet the following criteria:

- Are air compressors, as defined in section III.B.2;
- Are rotary or reciprocating compressors, as defined in section III.B.3;
- Are driven by a brushless electric motor, as defined in section III.B.4;
- Are distributed in commerce with a compressor motor nominal horsepower greater than or equal to 1 and less than or equal to 500 horsepower (hp) as defined in section III.B.5; and
- Operate at a full-load operating pressure of greater than or equal to 31 and less than or equal to 225 pounds per square inch gauge (psig), as defined in section III.B.6.

In this test procedure NOPR, DOE proposes to limit the applicability of the test procedure to compressor equipment being analyzed in the energy conservation standard. However, DOE notes that the broad definition of compressor provides DOE with flexibility to consider establishing test procedures and energy conservation standards for compressors outside the scope of this test procedure in the future.

2. Equipment System Boundary and Application

a. Equipment System Boundary

In the Framework Document for the compressor standards rulemaking, DOE considered three options for the equipment system boundary, based on the three different ways in which compressors are distributed in commerce: (1) as a bare compressor; (2) as a bare compressor, inclusive of driver(s) and mechanical equipment to drive the bare compressor; and (3) as a bare compressor, inclusive of driver(s) and mechanical equipment to drive the bare compressor, as well as all secondary equipment, componentry, and air conveyance equipment (i.e., a compressed air system (CAS)). DOE requested comment regarding the feasibility of covering each boundary level of compressor equipment.

In the Framework Document, DOE proposed no formal definitions for these equipment configurations. However, DOE described the term “bare compressor” as a “singular machine responsible for the change in air pressure, which is sometimes referred to as an ‘air end,’ and which is the compression chamber where air is compressed.” DOE specifically noted that this term would be exclusive of any other devices, such as an electric motor. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 6).

With respect to the “a bare compressor, inclusive of driver(s) and mechanical equipment to drive the bare compressor ” option (a compressor package), DOE described a configuration of compressor components that includes “a driver, such as an electric motor, and may include other equipment, such as gears, drains, air treatment (filtering) equipment, onboard controls, etc." DOE noted that this "configuration is considered the single largest piece of equipment brought to market by an individual manufacturer."[7]

With respect to the "a bare compressor, inclusive of driver(s) and mechanical equipment to drive the bare compressor, as well as all secondary equipment, componentry, and air conveyance equipment (i.e., a CAS)" option, DOE described a system "inclusive of all componentry that would be attached and would include components starting from the air intake and including the final 'point-of-use.'" DOE noted that under this option, "the compressor could include the many configuration packages that could be attached such as the distribution (piping) network, air-treatment systems, sequencers, storage tanks, and any end-use equipment (e.g., pneumatic tools)." (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 7).

In the Framework Document, DOE requested comment on the different equipment system boundary options. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 11). In response, Saylor-Beall commented that "while it might be possible to rate the air compressor package, attention needs to be given to the entire compressed air system of the end user." (Saylor-Beall, No. 0003 at p. 2)[8] Alternatively, Jenny Compressors ("Jenny") stated that "covering the entire 'CAS' may prove nearly impossible since many systems include components from many different manufacturers, and no two systems are

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[7] Ibid.
[8] A notation in this form provides a reference for information that is in the docket of DOE's rulemaking to develop test procedures for pumps (Docket No. EERE-2013-BT-TP-0055, which is maintained at www.regulations.gov). This particular notation refers to a comment: (1) submitted by HI; (2) appearing in document number 8 of the docket; and (3) appearing on page 4 of that document. This final rule also contains comments submitted in response to the pumps ECS rulemaking (Docket No. EERE-2011-BT-STD-0031) and such comments will be identified with that docket number.

the same.” (Jenny, No. 0005 at p. 2) CAGI and the Joint Commenters agreed that DOE should cover the compressor package as part of this rulemaking. (CAGI, No. 0009 at p. 3; Joint Comment, No. 0016 at p. 2) The Joint Commenters also stated that, if DOE covers the compressor package, DOE would need to ensure companies that assemble packages from purchased components are also subject to proposals in this rulemaking. (Joint Comment, No. 0016 at p. 2-3)

DOE considered these comments and reviewed the pros and cons of each equipment system boundary option. The following paragraphs discuss DOE’s finding and conclusions.

DOE considers covering a bare compressor to represent significantly lower energy savings compared to the other two equipment system boundary options. Logically, because a bare compressor is a subset of the compressor package and CAS, any energy savings available in the bare compressor would also be available in the compressor package and CAS options. Additionally, some energy savings opportunities are related to the ability to optimize a bare compressor relative to other components of the compressor package or CAS. Covering the bare compressor only would forgo the opportunity to realize those additional savings opportunities. Furthermore, some of those additional components have a significant impact on the energy consumption of the bare compressor in the field and are required for the bare compressor to function as intended. Consequently, DOE believes that determining the energy performance of the bare compressor alone would not be representative of the energy consumption of the equipment under typical use conditions. For these reasons, DOE does not propose to include bare compressors within the scope of applicability of this test procedure.

DOE also understands that, while the CAS represents the largest available energy savings, including the CAS in the scope of applicability of this rulemaking has significant drawbacks:

- Often a CAS is unique to a specific installation;
- Each CAS may include equipment from several different manufacturers; and
- A single CAS can include several different compressors, of different categories, which may all have different full-load operating pressures.

Implementing a broader, CAS-based approach to regulating compressor efficiency would require DOE to (1) establish a methodology for measuring losses in any arbitrary air-distribution network; and (2) assess what certification, compliance, and enforcement practices would be required for a potentially unlimited, and extremely variable, number of system designs. For these reasons, DOE does not propose to establish the scope of applicability of this test procedure to include CAS.

Based on the considerations stated above, at this time, DOE proposes to establish test procedures only for compressor packages, which contain bare compressors, driver(s), mechanical equipment to drive the bare compressor, and any ancillary equipment. DOE believes that determining the energy performance of compressors as a "compressor package" is the most representative of the energy consumption of the equipment under an average cycle of use.

b. Application

Broadly, compressors are used to compress a wide variety of gases, including, among others, air, natural gas, and refrigerants. In the Framework Document, DOE requested comment on limiting the scope to only "air compressors" and stated that information gathered to that point indicated that non-air compressing equipment accounted for a relatively small fraction of the overall compressors market, in terms of both shipments and annual energy consumption. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 4). In response, DOE received conflicting feedback on the topic from interested parties. The Edison Electric Institute (EEI) recommended covering all compressor categories regardless of the gas that is compressed because natural gas compressor energy use is projected to increase, while CAGI stated that DOE should cover only air compressors. (EEI, No. 0012 at p. 1-2; CAGI, No. 0009 at p. 1) The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) requested that compressors used in heating, ventilation, and air-conditioning (HVAC) equipment be specifically excluded. (AHRI No. 0015, at p. 1)

After the publication of the Framework Document, DOE announced several new initiatives to modernize the country's natural gas transmission and distribution infrastructure, including one to explore establishing efficiency standards for natural gas compressors.[9] As part of that effort, DOE published a Request for Information (RFI), on August 5, 2014, to help determine both the feasibility of energy conservation standards for natural gas compressors and whether they are similar enough to air compressors to be considered within the scope of this rulemaking. 79 FR 45377 (Aug. 5, 2014). Additionally, DOE announced the availability of a preliminary, high-level description of the market and available technology for natural gas compressors. (Docket No. EERE-2014-BT-STD-0051, No. 5). DOE held a public meeting on December 17, 2014, to present and seek comment on the content of that data. Based upon the feedback DOE received in response to the RFI and the NODA, DOE has determined that natural gas compressors are a unique style of compressors that serve different applications and market utility, which would necessitate unique test procedures and standards. As such, DOE opted to consider natural gas compressors separately from air compressors. (Docket No. EERE-2014-BT-STD-0051)

Regarding refrigerant compressors, DOE considers refrigerant compressors to have the same basic function as air compressors in that they both compress a working fluid to a higher pressure, but with the working fluid of refrigerant compressors being refrigerant instead of air. Refrigerant compressors are typically used in heating, ventilation, air-conditioning and refrigeration (HVACR) equipment. Similar to natural gas compressors, DOE has determined that refrigerant compressors serve a specific and unique application and also necessitate unique test procedures and standards. As such, DOE has opted not to consider refrigerant compressors in this rulemaking.

[9] See: http://energy.gov/articles/department-energy-announces-steps-help-modernize-natural-gas-infrastructure

Furthermore, DOE's research found no large market segments or applications for compressor equipment used with gases other than air, natural gas, and refrigerant. Information gathered during confidential manufacturer interviews also indicated that non-air and non-natural gas compressing equipment represented relatively low sales volume and annual energy consumption. Accordingly, for the forgoing reasons, DOE proposes to establish test procedures only for air compressors in this rulemaking.

c. Definition of Air Compressor

DOE proposes to define the term "air compressor" as a compressor designed to compress air that has an inlet open to the atmosphere or other source of air, and is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment.

The first clause of this definition the application of the compressor. The portion of the definition that states, "…a compressor designed to compress air that has an inlet open to the atmosphere or other source of air," describes what is commonly known as an air compressor and establishes that this definition includes air compressors only. DOE includes language regarding the compressor inlet as a secondary identifier of air compressors that focuses on features, so that the definition is not entirely reliant on assessment of design objectives. DOE notes that if this definition were to be adopted, DOE would refer to manufacturer literature, including operation and installation manuals, and any other representations made by the manufacturer when determining design intent.

The second clause of this definition discusses the equipment system boundary. Specifically, the portion of the definition which states, "…made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment." This clause describes the components that must be to be a regulated air compressor and subject to the proposed test procedure. These specific components are discussed and defined in section III.B.2.d.

DOE also notes that the proposed definition of air compressor is similar to the European Union's (EU's) Ecodesign Lot 31 Draft Standard of "basic package compressor," the ISO 1217:2009 definition of "packaged compressor," and DOE's own "compressor package" definition from the Framework Document, each of which is presented in the following paragraphs. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 6).

<u>EU Lot 31 Definition of "Basic Package Compressor"</u>

Basic package compressor means a compressor made up of compression element ('air end'), electric motor(s) and transmission or coupling to drive the compression element, and which is fully piped and wired internally, including ancillary and auxiliary items of equipment that is considered essential for safe operation and required for functioning as intended; (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 3).

ISO 1217:2009 Definition of "Packaged Compressor"

Packaged compressor means a compressor with prime mover, transmission, fully piped and wired internally, including ancillary and auxiliary items of equipment and being stationary or mobile (portable unit) where these are within the scope of supply.

Framework Document Definition of "Compressor Package"

Compressor package refers to the bare compressor plus a driver, such as an electric motor, and may include ancillary equipment such as gears, drains, air-treatment (filtering) equipment, onboard controls, etc. A compressor package is considered the single largest piece of equipment brought to market by an individual manufacturer. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 6).

d. Definition of Air Compressor Components

In order to explicitly establish the applicable components included in an air compressor, as defined, DOE must also define the terms "bare compressor," "driver," and "mechanical equipment." The following sections discuss DOE's proposed definitions for those terms.

Definition of "Bare Compressor"

In the Framework Document, DOE described a "bare compressor" as "[a] singular machine responsible for the change in air pressure and is sometimes referred to as an "air end," which is the compression chamber where air is compressed."

In this test procedure NOPR, DOE proposes a similar definition for "bare compressor." However, DOE's proposed definition expands upon and clarifies the discussion presented in the Framework Document to reference several specific design characteristics of bare compressors. Specifically, DOE proposes to include specific language from the definition for mechanical compressor included in ISO/TR 12942:2012[10] to define the term bare compressor. DOE's proposed definition of "bare compressor" reads as follows:

Bare compressor[11] means the compression element and auxiliary devices (e.g., inlet and outlet valves, seals, lubrication system, and gas flow paths) required for performing the gas compression process, but does not include the driver; speed-adjusting gear(s); gas processing apparatuses and piping; or compressor equipment packaging and mounting facilities and enclosures.

Definition of Driver

As discussed previously, another fundamental element of an air compressor is the driver, which provides mechanical power to drive a bare compressor. Examples include an electric motor, internal combustion engine, or gas turbine. In the Framework

[10] The definition of "mechanical compressor" in ISO 12942:2012 includes "compressor machine constituting essentially one or several working members movable in compression chambers and common built-in mechanism for conversion of external energy supply motion of the driver to the required working member motion, and being operable by supply of external mechanical energy from the power output shaft, or motion rod or piston of the driver or speed-adjusting driving gear. NOTE 1 The mechanical compressor contains necessary auxiliary devices for performing the gas compression process in the working chambers: applicable gas inlet and outlet valves, gas flow paths, seals, lubrication system, capacity control means, measuring instruments etc., but it does not contain driver, speed-adjusting gear, gas processing apparatuses and piping or compressor equipment packaging and mounting facilities and enclosures."

[11] The compressors industry frequently uses the term "airend" or "air end" to refer to the bare compressor. DOE uses "bare compressor" in the regulatory text of this proposed rule but notes that, for the purposes of this rulemaking, it considers the terms to be synonymous.

Document, DOE described and used the term driver, but did not offer a specific definition. In the recent pumps test procedure final rule, DOE defined the term, as it applies to pumps. 81 FR 4086 (Jan. 25, 2016). Specifically, the pumps test procedure final rule defines driver as "the machine providing mechanical input to drive a bare pump directly or through the use of mechanical equipment. Examples include, but are not limited to, an electric motor, internal combustion engine, or gas/steam turbine." Id. Due to the similarities between the equipment categories (i.e., equipment typically driven by electric motors and sometimes accompanied with variable frequency drives), in this NOPR, DOE proposes a definition for "driver" that is similar the one proposed in the pumps test procedure NOPR. DOE proposes a definition for the term "driver" to mean the machine providing mechanical input to drive a bare compressor directly or through the use of mechanical equipment.

Definition of Mechanical Equipment

An air compressor, as defined, may include mechanical equipment that serves to transfer energy from a driver to the bare compressor. In DOE's pumps test procedure final rule, DOE adopted a definition for mechanical equipment as "any component of a pump that transfers energy from a driver to a bare pump." 81 FR 4086 (Jan. 25, 2016). Again, due to the similarities between the equipment categories (i.e., equipment typically driven by electric motors and sometimes accompanied with variable frequency drives), DOE believes such a definition is also applicable to compressors and, as a result, in this NOPR, DOE proposes a definition for the term mechanical equipment as follows:

Mechanical equipment means any component of an air compressor that transfers energy from the driver to the bare compressor.

Definition of Ancillary Equipment

DOE believes that the energy consumption of all components distributed in commerce with an air compressor should be considered when evaluating the energy performance of the air compressor. Consequently, DOE proposes to define ancillary equipment as any equipment distributed in commerce with an air compressor that is not a bare compressor, driver, or mechanical equipment. DOE notes that ancillary equipment would be considered to be part of a given air compressor model, regardless of whether the ancillary equipment is physically attached to the bare compressor, driver, or mechanical equipment at the time when the air compressor is distributed in commerce.

DOE requests comment on its proposed definition of air compressor and its use in limiting the scope of applicability of this test procedure.

DOE requests comment on the proposed definitions for bare compressor, driver, and mechanical equipment.

DOE requests comment on the proposed definition of ancillary equipment, and whether a comprehensive list of potential ancillary equipment is more appropriate. If a comprehensive list of potential ancillary equipment is preferred, DOE requests information on what equipment should be on that list.

DOE requests comment on its position that all ancillary equipment distributed in commerce with an air compressor be installed when testing to evaluate the energy performance of the air compressor. DOE requests comment on a potential alternative approach, in which DOE could generate a list of specific ancillary equipment that must be installed to ensure that the test result is representative of compressor performance; equipment on this list would not be optional, regardless of how that compressor model is distributed in commerce. If the alternative approach is preferred, DOE requests comments on what ancillary equipment be required to be installed to representatively measure compressor energy performance and how to evaluate compressor performance if an air compressor is distributed in commerce without certain items on the list.

3. Compression Principle

Compressor equipment can use a variety of different compression mechanisms in order to increase the pressure of the gas. The three main compressor categories each rely on a different compression principle and include rotary compressors, reciprocating compressors, and dynamic compressors. In the Framework Document, DOE offered definitions for each of these compressor equipment categories as follows:

Dynamic compressor means a compressor in which the increase in gas pressure is achieved continuously by increasing the kinetic energy of the working fluid in the flow path of the equipment due to acceleration to high velocities by mechanical action of blades placed on a rapid rotating wheel and further transformation of the kinetic energy into potential energy by successive deceleration of the working fluid flow rate and associated pressure increase.

Rotary compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes or its forced discharge are performed cyclically by rotation of one or several rotors in a compressor casing.

Reciprocating compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes are performed cyclically by straight-line alternating movements of a moving member(s) in a compression chamber(s).

In the Framework Document, DOE requested comment on which compression categories should be considered for inclusion in the scope of DOE's rulemaking efforts. In response, several interested parties agreed that DOE should cover all three compressor categories. (Joint Comment, No. 0016 at p. 2; CAGI, No. 0009 at p. 1) Scales commented that DOE should focus on centrifugal and rotary screw compressors above 350 hp. (W. Scales, No. 0020 at p. 1) DOE also received annual shipments data, differentiated by these compressor categories, in industry stakeholder submittals.

In response to the submitted comments, DOE researched the characteristics, typical usage and applications, and available test methods for the different compressor categories. DOE research indicated that dynamic compressors are typically larger in horsepower than positive displacement compressors, and commonly engineered specifically for a unique customer or application. In addition, DOE found that the standard international test procedure for dynamic compressors, ISO 5389, is considered too complicated and not widely used by industry. As a result of the specialization of dynamic compressor equipment and the complexity of the industry test procedure, very little application and performance data are publicly available, which makes it difficult for DOE to assess the feasibility or representativeness of ISO 5389 or other test procedures for this equipment. In addition, due to the unique industry test procedure and applications of dynamic compressors, DOE believes it is most appropriate to apply a unique test procedure to such equipment. Conversely, ISO 1217:2009 is applicable to both rotary and reciprocating compressors and is currently widely used by the industry for testing and verifying equipment performance. For further details on ISO 1217:2009 see section III.D.

Based on the shipments data submitted by interested parties in response to the Framework Document, DOE also estimated the overall size of the air compressors market for each configuration. The shipments data for 2013 provided to DOE suggest that rotary and reciprocating compressors account for the majority of the air compressors market by units shipped. By contrast, dynamic compressors account for fewer than 300 total units shipped, or roughly one percent of the total market. Because rotary and reciprocating compressors can be tested in the same manner and represent the majority of the market, DOE is electing to consider a test procedure that is applicable only to rotary and reciprocating compressors. DOE may create test procedures for dynamic compressors in the future and notes that, due to the differences from rotary and reciprocating compressors, it would be most appropriate to address the test procedure for dynamic compressors as part of a separate rulemaking.

To establish the applicability of the test procedure proposed in this NOPR, DOE proposes the following definitions for rotary and reciprocating compressors, which are consistent with those discussed in the Framework Document:

Rotary compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes or its forced discharge are performed cyclically by rotation of one or several rotors in a compressor casing. This definition for rotary compressor is consistent with the definition included in ISO/TR 12942:2012 and is currently used within the compressor industry.

Reciprocating compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes are performed cyclically by straight-line alternating movements of a moving member(s) in a compression chamber(s). This definition for reciprocating compressor is consistent with the definition included in ISO/TR 12942:2012 and is currently used within the compressor industry.

To support the previous definitions, DOE also proposes to define the term positive displacement compressor as a compressor in which the admission and diminution of successive volumes of the gaseous medium are performed periodically by forced expansion and diminution of a closed space(s) in a working chamber(s) by means of displacement of a moving member(s) or by displacement and forced discharge of the gaseous medium into the high-pressure area. This definition for positive displacement compressor is consistent with the definition included in ISO/TR 12942:2012 and is currently used within the compressor industry.

DOE requests comment on its proposed definitions of rotary compressor, reciprocating compressor, and positive displacement compressor and their use in defining the scope of applicability of this test procedure.

4. Styles of Drivers

a. Electric Motor- and Engine-Driven Compressors

Compressors can be powered using several different kinds of drivers, commonly including electric motors and internal combustion engines. Electric motor-driven equipment may use either single-phase or three-phase electric motors. Engine-driven[12] compressors can be powered by using different kinds of fuels, commonly including diesel, gasoline, and natural gas. In the Framework Document, DOE considered covering all compressors regardless of driver design and requested comments from interested parties.

DOE received varying comments regarding the inclusion of engine-driven compressors. Jenny, the Association of Equipment Manufacturers (AEM), and Sullair recommended excluding engine-driven compressors due to the burden imposed by current emissions regulations and overall low energy consumption by these products. (Jenny, No. 0005 at p. 2; AEM, No. 0011 at p. 1-2; Sullair, No. 0013 at p. 2) EEI and the CA IOUs urged DOE to include engine-driven compressors to avoid creating a market trend towards engine-driven compressors. (EEI, No. 0012 at p. 2-3; CA IOUs, No. 0018 at p. 2) The joint Commenters recommended that DOE examine engine-driven

[12] For the purposes of this document, the term "engine" means "combustion engine," equipment which can convert chemical energy into mechanical energy by combusting fuel in the presence of air.

compressors to evaluate possible energy savings but noted that generally they are used in low-duty cycle applications. (Joint Comment, No. 0016 at p. 2)

In response to comments submitted by interested parties, DOE investigated engine-driven air compressors and found that they are generally portable and designed to be used in environments where access to electricity is limited or non-existent, particularly at the current or voltage levels required by comparable electric motor-driven compressors. Engine-driven air compressors are also typically used as on-demand units, with a low duty cycle and annual energy consumption. Additionally, engine-driven air compressors, by nature of their portability, are difficult to optimize for a specific set of operating conditions, which may affect their efficiency relative to a stationary unit that is designed or selected with a specific load profile in mind. Consequently, engine-driven and electric motor-driven air compressors do not serve the same applications or utility in the marketplace and are not mutual substitutes.

DOE is aware that engine-driven air compressors are currently covered by the Environmental Protection Agency's Tier 4 emissions regulations (40 CFR 1039). DOE understands that these Tier 4 regulations have resulted in market-wide redesigns for the engines typically used in these compressors, which has required compressor manufacturers to redesign some aspects of the bare compressor as well. DOE recognizes that any regulations established for engine-driven compressors may result in incrementally more burdensome testing requirements for such equipment and potential design changes that conflict with those required for compliance with Tier 4 regulations.

Additionally, the industry standard test method proposed for incorporation into this test procedure, Annex C of ISO 1217:2009, is the most widely-used test method for determining performance of electric motor-driven compressors. However, Annex C of ISO 1217:2009 does not apply to engine-driven compressors. DOE notes that Annex D of ISO 1217:2009, which is not proposed for incorporation into this test procedure, is intended to address engine-driven compressors. However, unlike Annex C of ISO 1217:2009, DOE currently lacks testing and performance data related to Annex D of ISO 1217:2009. Consequently, DOE is unable to verify the repeatability and applicability of Annex D of ISO 1217:2009 at this time.

Due to the lack of testing and performance data from Annex D of ISO 1217:2009, as well as the difference in market, application, and applicable industry test procedure; DOE proposes to exclude engine-driven air compressors from the scope of applicability of the test procedure proposed in this rulemaking. However, DOE may consider a test procedure for engine-driven compressors as part of a future rulemaking.

b. Styles of Electric Motor

Motors used in compressors broadly fall into two categories: brushed and brushless. Brushed motors perform “commutation” – changing the direction of the electric field as the motor’s rotor turns – using a sliding electrical contact, or “brush.” Brushless motor technologies may vary widely in how they accomplish commutation, but have in common the absence of brushes.

DOE is aware that some small compressors intended for very low duty cycle applications may be manufactured with motors which use brushes. Although brushes are simple to control and inexpensive to construct, they are rarely used in applications with significant operating hours for several reasons. First, brushes generally are less efficient than brushless technology, and are therefore suitable only for applications with low duty cycles. Second, brushes wear and require replacement at regular intervals, which may result in costly downtime in an industrial process. Third, brushes may create electrical arcing, rendering them unsuitable for certain industrial environments where combustible or explosive gases or dusts may exist. Finally, brushes may create more noise than brushless technology, and quieter equipment is often viewed as an important and attractive attribute by an end-user. All of these factors limit the applications suitable for compressors manufactured with brushed motors. However, DOE recognizes there is a unique market segment in which brushed motors are appropriate, such as specific applications in which operating life and durability are not important criteria. As a result, DOE believes that any test procedure designed for compressors sold with brushed electric motors would require a unique load profile in order to accurately reflect a representative average use cycle, as required by EPCA. (42 U.S.C. 6314(a)(2)) DOE also notes that, because compressors sold with brushed motors play a specialized and minor role in the compressors market, they are not associated with significant energy consumption. Consequently, DOE proposes to limit the scope of the test procedure to only those compressors that are driven by brushless motors. DOE may consider separate test procedures or energy conservation standards for compressors sold with brushed electric motors as part of a separate rulemaking.

For the purposes of establishing the applicability of this test procedure rulemaking, DOE proposes to define a brushless electric motor as a machine that converts electrical power into rotational mechanical power without use of sliding electrical contacts. DOE considers brushless motors to include, but not be limited to, what are commonly known as induction, brushless DC, permanent magnet, electrically commutated, and reluctance motors. The term brushless motors would not include what are commonly known as brushed DC and universal motors.

DOE requests comment on its proposal to establish test procedures for only brushless electric motor-driven equipment and on its proposed definition of brushless electric motor.

5. Compressor Capacity (Compressor Motor Nominal Horsepower)

Compressors are sold in a very wide range of capacities. Compressor capacity refers to the overall rate at which a compressor can perform work. Although the ultimate end-user requirement is a specific output volume flow rate of air at a certain pressure, industry typically describes compressor capacity in terms of the "nominal" horsepower of the motor. As a result, in this rulemaking, DOE proposes to consider compressor capacity in terms of the "nominal" horsepower of the motor with which the compressor is distributed in commerce.

DOE recognizes that although the term nominal motor horsepower is commonly used within the compressor industry, it is not explicitly defined in ISO 1217:2009. To alleviate any ambiguity associated with these terms, DOE proposes to define the term "compressor motor nominal horsepower" to mean the motor horsepower of the electric motor, as determined in accordance with the applicable procedures in subpart B and subpart X of part 431, with which the rated air compressor is distributed in commerce.

In the Framework Document, DOE discussed limiting the scope of applicability based on compressor capacity as measured in horsepower (hp) to units with capacities of between 1 to 500 hp in order to align the scope of compressor standards with the scope of DOE's electric motors standards. See 10 CFR 431.25. Commenters generally recommended expanding the scope to cover compressors larger than 500 hp, in order to capture the maximum possible energy savings that may result from the combined impacts of this test procedure rulemaking and the associated energy conservation standard rulemaking. (EEI, No. 0012 at p. 3; Joint Comment, No. 0016 at p. 2; Natural Resource Defense Council (NRDC), No. 0019 at p. 1; CA IOUs, No. 0018 at p. 2) Jenny and the Joint Commenters also recommended that the lower hp limit should be increased due to the low annual energy usage of compressors under 10 hp. (Jenny, No. 0005 at p. 3; Joint Comment, No. 0016 at p. 2)

DOE considered the comments of interested parties regarding the range of equipment capacities considered in this test procedure rulemaking. Shipment data, broken down by rated capacity and compressor style (i.e., rotary, reciprocating, and dynamic) indicate that units above 400 hp represent less than 1 percent of the rotary market and virtually none of the reciprocating market. Although it is possible to build positive displacement compressors above 500 hp, shipments are very low and the equipment is typically custom-ordered. DOE notes that, above 500 hp, dynamic compressors are the dominant choice for industrial compressed air service. However, as discussed previously in section III.B.3, the proposed test procedure would not apply to dynamic compressors. Additionally, less performance data is available on units with capacities greater than 500 hp and therefore it is difficult to determine the suitability of the proposed test procedure provisions to such large equipment. Further, testing such large capacity equipment may require more specialized equipment that is less commonly available and would increase the burden associated with conducting the test procedure. Regarding the lower end of the capacity range (i.e., 1 hp), DOE notes that available shipment data indicates that compressors 10 hp and below, while consuming less power on a per-unit basis, account for more than a quarter of fixed-speed, rotary units shipped. DOE believes the proposed test procedures are suitable for measuring the performance of such units, and would not preclude the possibility of cost effective energy savings without performing analysis. As a result, DOE proposes limiting the scope of this test procedure to air compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 hp. Based on available shipment data, DOE's proposal is expected to cover nearly the entirety of the rotary and reciprocating compressor market.

DOE requests comment on its proposed definition of compressor motor nominal horsepower. Additionally, DOE seeks comment on whether motors not currently subject to the test procedure requirements in subpart B and subpart X of part 431 are incorporated into air compressors within the scope of this proposed test procedure. If so, DOE requests comment on how prevalent these motors are, and whether the test methods described in subpart B and subpart X of part 431 would be applicable to determine the compressor motor nominal horsepower of such motors. If the test methods described in subpart B and subpart X of 10 CFR part 431 are not applicable to motors not subject to DOE's current Federal test procedures for small electric or electric motors, DOE requests comment on what test methods could be used to determine their compressor motor nominal horsepower.

DOE requests comment on the proposal to include only compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 within the scope of this test procedure.

6. Output Pressure Range

DOE also proposes in this NOPR to limit the applicability of the test procedure based on the full-load operating pressure of the equipment. Specifically, DOE proposes that the test procedure only be applicable to compressors with full-load operating pressures greater than or equal to 31 psig and less than or equal to 225 psig. DOE believes this range represents the majority of the reciprocating and rotary compressor market. In the Framework Document, DOE discussed limiting the scope of this initial compressor test procedure based on the full-load operating pressure of the compressors. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 8). However, in the Framework Document, DOE used the comparable terms "absolute discharge pressure" and "absolute gauge output pressure." (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 19). DOE also notes that the full-load operating pressure is related to the pressure ratio, discussed previously in section III.A, but describes the absolute increase in pressure, whereas the pressure ratio represents the pressure increase expressed as a multiple of the inlet pressure of the compressor.

In response to the Framework Document, CAGI noted that industry generally considers compressors to have a pressure ratio of greater than 2.5. (CAGI, No. 0009 at p. 1) In a separate submission, CAGI provided the following more detailed breakdown of the rotary compressors market:

- Approximately 4.4 to 30 pounds per square inch gauge (psig) (pressure ratio greater than 1.3 and less than or equal to 3.0): The compressors industry generally refers to these products as blowers—a term DOE is considering defining as part of its fans and blowers rulemaking (Docket No. EERE-2013-BT-STD-0006). The majority of these units are typically distributed in commerce as bare compressors and do not include a driver, mechanical equipment, or controls.
- 31 to 79 psig (pressure ratio greater than 3.1 and less than or equal to 6.4): There are relatively few compressed air applications in this pressure range, contributing to both low product shipment volume and low annual energy consumption.
- 80 to 139 psig (pressure ratio greater than 6.4 and less than or equal to 10.5): This range represents the majority of general compressed air applications, shipments, and annual energy use.

- 140 to 215 psig (pressure ratio greater than 10.5 and less than or equal to 15.6): This range represents certain specialized applications, relatively lower sales volumes and annual energy consumption when compared to the 80 to 139 psig rotary compressor segment.
- Greater than 215 psig (pressure ratio greater than 15.6): This range represents even more specialized applications, which require highly engineered rotary compressors that vary based on each application.

(CAGI, No. 0030 at p. 4)

DOE did not receive any additional information that separated the market of reciprocating compressors by pressure. According to the Lot 31 preparatory study final report[13], single- and two-stage reciprocating compressors typically operate from 0.8 to 12 bar (12 to 174 psig; pressure ratio 1.8 to 13), and multi-stage reciprocating compressors typically operate from 12 to 700 bar (174 to 10,152 psig; pressure ratio 13 to 701). However, based on market research and discussions with various compressor manufacturers, DOE believes that pressure ranges for reciprocating compressors are similar to rotary compressors.

Based on DOE's research and information from commenters, DOE proposes to apply the test procedure to compressors with full-load operating pressures of between 31

[13] For copies of the EU Lot 31 draft regulation: www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf.

and 225 psig (pressure ratios greater than ~3.1 and less than or equal to 16.3). DOE notes that while some commenters suggested an upper limit of 215 psig, full-load operating pressure values may be generated differently by each manufacturer and it is not clear that they are completely comparable between manufacturers.[14] For example, a product listed at 215 psig from one manufacturer may compete with a product listed at 217 psig from another, which may compete with one listed at 212 psig from a third. Although DOE's proposed test procedure seeks to eliminate this issue (see specifically, section III.D.2.i), DOE must still account for the current lack of consistent pressure rating methodology in the compressor industry. As a result, DOE proposes to adopt an upper limit of 225 psig to include the majority of non-special purpose equipment DOE could identify on the market. Compressor equipment with full-load operating pressures below 31 psig and above 225 psig generally serve applications that do not often overlap with the 31-225 psig compressor market and do not represent a significant volume of sales. DOE notes that equipment with full-load operating pressures below 31 psig and above 225 psig may still meet the proposed definition of air compressor. DOE may consider extending test procedure applicability to these compressors in a future rulemaking.

DOE requests comment on its characterization of the rotary compressor market by pressure ranges, and whether the reciprocating compressor market is similarly characterized.

[14] DOE notes that there is no universally accepted procedure for establishing full-load operating pressure and, thus, no assurances that values are comparable.

As the full-load operating pressure would be used to determine the applicability of the proposed test procedure, it is important that the full-load operating pressure be established consistently amongst compressor models. To that end, DOE proposes to establish a specific definition and procedure for determining full-load operating pressure for applicable compressors, which is based on the maximum full-flow operating pressure. Specifically, DOE proposes to define the term full-load operating pressure as follows:

Full-load operating pressure means the represented value of discharge pressure, which must be greater than or equal to 90 percent and less than or equal to 100 percent of the maximum full-flow operating pressure. The term full-load operating pressure is commonly used in the compressors industry to characterize compressor output air pressure and appears as a listed parameter on CAGI's voluntary performance verification data sheets. Additionally, the EU Lot 31 draft standard[15] characterizes compressor output pressure using a nearly identical term, "full load outlet pressure." DOE proposes this definition of full-load operating pressure in order to characterize compressor output pressure in a manner consistent with both the U.S. industry and the European standard, and to ensure reproducible and comparable representations among the different manufacturers and models. Specifically, DOE understands the full-load operating pressure to be a nominal term at which manufacturers elect to produce ratings. For example, the CAGI datasheets define the term as "the operating pressure at which the capacity and electrical consumption were measured for this data sheet."[16] Therefore,

[15] http://www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf
[16] See, for example, http://www.cagi.org/pdfs/Fixed%20Speed%20Datasheet%2010-11%20rev8.pdf.

DOE is defining the term "full-load operating pressure" to be a nominal, self-declared value that is within a certain range of the actual, measured maximum full-flow operating pressure.

While DOE understands the need to provide manufacturers some discretion with regard to the selection of the full-load operating pressure, specifying that the selected nominal value is within 10 percent of the actual, tested maximum full-flow operating pressure ensures that the self-declared value is in fact representative of the equipment's capacity and provides better consistency and comparability among ratings. As the proposed definition of full-load operating pressure references the maximum full-flow operating pressure, DOE also proposes a definition and test method (discussed in section III.D.2.i) for maximum full-flow operating pressure. Specifically, the maximum full-flow operating pressure is defined as the maximum discharge pressure at which the compressor is capable of operating as determined in accordance with the methods described in the applicable section of the compressor test procedure.[17] This is the actual maximum operating pressure of the equipment, consistent with the CAGI definition of the term, which describes the maximum full-flow operating pressure as maximum pressure attainable at full flow, usually the unload pressure setting for load/no load control or the maximum pressure attainable before capacity control begins. In the case of the term full-load operating pressure, there is a corresponding flow term, full-load actual volume flow rate, which DOE proposes to define as the actual volume flow rate of the compressor at the full-load operating pressure. The full-load actual volume flow rate is a

[17] In the definition proposed in section 10 CFR 431.344, this language refers to the appropriate section number of the regulatory text as it would appear in the Code of Federal Regulations.

dependent value and is determined through measurement at the full-load operating pressure, as determined in section III.D.2.i.

The proposed definition of full-load actual volume flow rate mentions the actual volume flow rate of the equipment; therefore, DOE must also define the term actual volume flow rate. ISO 1217:2009 defines a similar term, actual volume flow rate of a compressor, as the actual volume flow rate of gas, compressed and delivered at the standard discharge point, referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point.[18] Assuming, as proposed, this test procedure applies only to air compressors, DOE's proposes the following, similar definition:

Actual volume flow rate means the volume flow rate of air, compressed and delivered at the standard discharge point, referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point.

DOE notes that the terms standard discharge point, total temperature, total pressure, and [gas] composition are explicitly defined in ISO 1217:2009, and DOE proposes to incorporate these definitions by reference. DOE also notes that the term "referred to," which is common compressor industry parlance, is synonymous with the term "normalized to." In both cases, the objective is to characterize measured values with respect to a common reference point so that they may be more easily compared. In

[18] This language also describes the parameter called "corrected volume flow rate," which works out to be equivalent to "actual volume flow rate" and is addressed in this section.

this case, the reference point is the measured atmospheric conditions at the compressor inlet point. The compressor industry describes this practice as "referring" the values to inlet conditions. In the interest of harmonization with the definition supplied in ISO 1217:2009, DOE proposes to keep the term "referred to" in its definition of actual volume flow rate.

DOE also proposes that actual volume flow rate be measured in accordance with section C.4.2.1 of annex C of ISO 1217:2009. DOE notes that section C.4.2.1 of annex C of ISO 1217:2009 refers to a parameter called "corrected volume flow rate;" for the purposes of this test procedure, DOE proposes that the terms corrected volume flow rate and actual volume flow rate be deemed equivalent and synonymous. Section C.4.2.1 of annex C of ISO 1217:2009 also includes a correction factor for shaft speed, which is clarified in section C.4.2.2 of annex C of ISO 1217:2009 as "only required when the electric motor drive is not supplied." As described in section III.B.2, DOE is proposing to establish test procedures only for compressor packages, which always include a driver (i.e., electric motor). Therefore, DOE proposes to specify that the correction factor for shaft speed in section C.4.2.1 of annex C of ISO 1217:2009 is not to be used.

DOE requests comment on the proposed definitions of full-load operating pressure, maximum full-flow operating pressure, and full-load actual volume flow rate, and actual volume flow rate.

DOE requests comment on the proposal to include only compressors with a full-load operating pressure greater than or equal to 31 psig and less than or equal to 225 psig within the scope of this test procedure.

C. Energy-Related Metrics

1. Specific Input Power and Isentropic Efficiency

In the Framework Document, DOE discussed the two most common metrics used in the compressor industry today to describe the performance of air compressors: package specific power and package isentropic efficiency. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 10-11). Package specific power is the compressor power input at a given load point, divided by the actual volume flow rate at the same load point, as determined in accordance with the methods described in section III.C.1. Further discussion of the relevant portions of ISO 1217:2009 and DOE's proposal to incorporate it by reference is found in section III.D of this document. DOE notes that section C.4.4 of annex C of ISO 1217:2009 refers to "specific energy consumption." For the purposes of this test procedure, the terms specific energy consumption and package specific power are interchangeable.

Package isentropic efficiency is the ratio of power required for an ideal isentropic compression process at a given load point[19] to the actual packaged compressor power input used at the same load point, as determined in accordance with the methods described in section III.C.4 and III.C.5.

[19] Or a weighted average of several, specified load points.

The two metrics under consideration provide similar but different information. Package specific power provides users with a way to directly calculate the power required to deliver a particular flow rate of air; this metric is currently used by the CAGI Voluntary Performance Verification Program to characterize compressor performance.[20] However, package specific power calculations are only valid at the output pressure at which a unit is tested and cannot be used to compare units operating at different pressures.

Package isentropic efficiency measures how efficiently a compressor package delivers a given flow rate of air. Package isentropic efficiency is relative to an ideal isentropic process and therefore can be used to compare units across a wide range of pressures. DOE notes that the EU has adopted package isentropic efficiency as the regulatory metric in their draft air compressor regulation.[21]

In the Framework Document, DOE requested feedback regarding both metrics and which would be more appropriate for any potential compressors energy conservation standard. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 11). The Joint Commenters and NRDC commented that both package specific power and package isentropic efficiency should be considered to provide end users with the most information possible when making purchasing decisions. (Joint Comment, No. 0016 at p. 3; NRDC, No. 0019 at p.1; and NRDC, No. 0019 at p. 2) The CA IOUs recommended that a part-

[20] http://cagi.org/performance-verification/overview.aspx.
[21] Available at: http://www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf

load test metric be used to assist in the design optimization of compressor systems with multiple compressors. (CA IOUs, No. 0018 at p. 3)

The following section discusses DOE's selected metric and DOE's rationale for selecting it.

2. Selected Metric: Package Isentropic Efficiency

After careful consideration of Framework Document comments and additional feedback received during interviews with manufacturers, DOE proposes to adopt package isentropic efficiency as the representative metric for describing the energy performance of certain compressors.

However, DOE notes that package isentropic efficiency, as introduced in section III.C.1, is a generic metric applicable to all load points. Therefore, DOE must define a load point (or load points) for the purpose of determining a reproducible and comparable efficiency rating for each compressor model. Kaeser corroborated this idea in its comment, and stated that ISO 1217:2009 provides instructions for how to perform testing but does not specify at what points to perform said tests. (Kaeser Compressors, No. 0040 at p. 94) In relation to load points and the proposed metric, NEEA requested that the test procedure account for variable-speed compressors, while the CA IOUs recommended that DOE include a part-load efficiency metric. (NEEA, No. 0040 at p. 92; and CA IOUs, No. 0018 at p. 3). DOE agrees that part-load performance may be valuable for users of variable-speed compressors. However, DOE believes that a part-load performance metric would not be applicable to all fixed-speed compressors, as many of these compressors are not designed to operate at part-load.

Consequently, DOE proposes to establish two versions of package isentropic efficiency: full-load package isentropic efficiency and part-load package isentropic efficiency. Full-load package isentropic efficiency would apply only to fixed-speed compressors, whereas part-load package isentropic efficiency would apply only to variable-speed compressors. Full-load isentropic efficiency is evaluated at a single load point, while part-load isentropic efficiency is a weighted composite of performance at multiple load points (or rating points). This structure follows the structure of the draft EU compressors regulation and is consistent with the previously discussed interested party comments. DOE believes these metrics and load points provide the best representation of energy consumption for fixed- and variable-speed equipment, respectively.

Equations 1 and 2 describe the full- and part-load package isentropic efficiency. Further details on the calculation of these metrics are contained in sections III.C.4 and III.C.5. Further details on load points and weighting are discussed in section III.C.3.

$$\eta_{\mathrm{isen,FL}} = \frac{P_{\mathrm{isen,100\%}}}{P_{\mathrm{real,100\%}}}$$

Eq. 1

Where:

$\eta_{isen,FL}$ = package isentropic efficiency at full-load operating pressure,

$P_{isen,100\%}$ = isentropic power required for compression at full-load operating pressure, and

$P_{real,100\%}$ = packaged compressor power input at full-load operating pressure.

$$\eta_{isen,PL} = \sum_{i} \omega_i \frac{P_{isen,i}}{P_{real,i}}$$

Eq. 2

Where:

$\eta_{isen,PL}$ = part-load package isentropic efficiency,

ω_i = weighting factor for rating point i,

$P_{isen,i}$ = isentropic power required for compression at rating point i,

$P_{real,i}$ = packaged compressor power input at rating point i, and

i = selected rating points.

In order to clearly separate the two groups of compressors, DOE proposes the following definitions for fixed-speed and variable-speed compressors.

<u>Fixed-speed compressor</u> means an air compressor that is not capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor flow rate.

Variable-speed compressor means an air compressor that is capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor actual volume flow rate.

The proposed definition for fixed-speed compressor encompasses compressors that use single speed and multi-speed drivers. Both definitions are based on the definitions for non-continuous control and continuous control, respectively, as adopted in DOE's pumps test procedure final rule, due to the similarities between compressors and pumps. 81 FR 4086 (Jan. 25, 2016).

The following section discusses load points for both full-load and part-load package isentropic efficiency.

3. Load Points and Weighting Factors for Calculating Full-Load and Part-Load Isentropic Efficiency

DOE reviewed the load points and weighting factors used by current industry programs. For fixed-speed compressors, the CAGI Performance Verification Program specifies testing at two load points: (1) flow rate at full-load operating pressure and (2) zero flow rate. In contrast, the European Union's draft air compressors regulation[22] specifies testing fixed-speed compressors only at full-load.

[22] Available at: http://www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf

For variable-speed compressors, the CAGI Performance Verification Program references Annex E of ISO 1217:2009 and specifies testing at a minimum of six load points:

- maximum volume flow rate,
- three or more volume flow rates evenly spaced between the minimum and maximum volume flow rate,
- minimum volume flow rate, and
- no-load power.

In contrast, the European Union's draft air compressors regulation[23] specifies testing variable-speed compressors at only three designated load points; 40, 70, and 100 percent of the flow rate measured at full-load operating pressure (or maximum flow rate).

DOE believes that the EU's draft approach of requiring testing at only three load points would reduce the burden of testing while still providing an accurate representation of the unit's part-load performance. Further, by stipulating specific load points for testing rather than evenly spaced load points, the EU method ensures that all variable-speed compressors are tested at the same load points, resulting in simple and accurate comparisons across equipment models. Consequently, DOE proposes to adopt the same load profiles for fixed-speed and variable-speed compressors as those published in the draft EU air compressors regulation. These load points are summarized in Table III.2.

[23] Available at: http://www.regulations.gov/contentStreamer?documentId=EERE-2013-BT-STD-0040-0031&disposition=attachment&contentType=pdf.

Table III.2 Load Profiles Based on Compressor Configuration

Compressor Configuration	Load Profile	Load Points
Fixed-speed compressors	Full-Load	Maximum flow rate
Variable-speed compressors	Part-Load	40, 70, and 100 percent of maximum flow rate

As first discussed in section III.C.2, and shown in equation 2, the part-load package isentropic efficiency metric requires a weighting factor for each load point in order to calculate the final part-load package isentropic efficiency. These weighting factors are meant to represent the percentage of operating time the compressor is operating at each load point. The draft EU air compressors regulation, after which DOE modeled its proposed part-load efficiency calculation, specifies weights of 25, 50, and 25 percent; at load points of 40, 70, and 100 percent of maximum flow, respectively. DOE notes that the CAGI Performance Verification Program does not use a weighted average part-load metric, and thus does not provide weighting factors.

DOE found no other weighting factors currently in use within the compressor industry. Additionally, DOE was unable to find real-world, representative load profile data for equipment in the field. In the absence of representative load profile data, DOE proposes adopting the EU load weighting factors, which would allow for direct and equitable comparisons between equipment, since the weighting factors would be applicable to all variable-speed equipment. In addition, DOE believes these weighting factors adequately represent the operating range of variable-speed compressors and would not be unduly burdensome to conduct, since compressor manufacturers may already perform such testing in support of compliance with the EU regulations. Table

III.3 summarizes DOE's proposal for weighting factors for the part-load package isentropic efficiency metric.

Table III.3 Weight Values for Specified Part-Speed Compressor Load Profile

Load Point (percent of maximum flow rate)	Weighting Factors (ω_i as specified in equation 6)
40	0.25
70	0.50
100	0.25

DOE requests comment on the proposed load points and weighting factors for package isentropic efficiency for both fixed-speed and variable-speed compressors.

4. Full-Load Isentropic Efficiency

As discussed in section III.C.2, DOE proposes to rate fixed-speed compressors with the full-load isentropic efficiency metric. This section discusses, in detail, the formulas needed to calculate full-load isentropic efficiency for fixed-speed compressors. DOE notes that certain inputs to these formulas are measured or calculated using ISO 1217:2009, certain sections of which DOE proposes to incorporate by reference (see section III.D). For these inputs, DOE has referenced the specific locations within ISO 1217:2009 where those values or procedures may be found. Complete details on ISO 1217:2009, and DOE's justification for its use in this test procedure, are discussed in section III.D.

As discussed in section III.C.3, full-load package isentropic efficiency is calculated at one load point: full-load operating pressure. The equation for full-load package isentropic efficiency is as follows:

$$\eta_{isen,FL} = \eta_{isen,100\%} = \frac{P_{isen,100\%}}{P_{real,100\%}}$$

Eq. 3

Where:

$\eta_{isen,FL} = \eta_{isen,100\%}$ = package isentropic efficiency at full-load operating pressure and 100 percent of full-load actual volume flow rate,

$P_{real,100\%}$ = packaged compressor power input at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined from equation 4[24], and

$P_{isen,100\%}$ = isentropic power required for compression at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined from equation 5.

As referenced in equation 3, the packaged compressor power input at full-load operating pressure and 100 percent of full-load actual volume flow rate is determined in accordance with equation 4:

$$P_{real,100\%} = K_5 \cdot P_{PR,100\%}$$

[24] The correction factor for the shaft speed (K_4) in section C.4.3.1 of annex C in ISO 1217:2009 is not applicable to this test procedure because the electric motor drive is included in the package, and it is therefore omitted from this equation.

Eq. 4

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009 at a contractual inlet pressure of 100 kPa,[25] and

$P_{PR,100\%}$= packaged compressor power input reading at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

The isentropic power required for compression at full-load operating pressure and 100 percent of full-load actual volume flow rate ($P_{isen,100\%}$), shown in equation 5, is evaluated using measurements taken while the unit is operating at full-load operating pressure:

$$P_{isen,100\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa-1}{\kappa}} - 1 \right]$$

Eq. 5

[25] The correction factor for inlet pressure uses contractual values for inlet pressure. Since a contractual value is not applicable to this test procedure, DOE proposes to use a value of 100 kPa from annex F in ISO 1217:2009.

Where:

$\dot{V}_{1\_m3/s}$ = corrected volume flow rate at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = Atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

p_2 = discharge pressure at full-load operating pressure and 100 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which, for the purposes of this test procedure, is 1.400.[26]

DOE requests comment on its proposed definition for full-load package isentropic efficiency, and its use as the metric for fixed-speed compressors.

5. Part-Load Isentropic Efficiency

As discussed in section III.C.2, DOE proposes to rate variable-speed compressors with the part-load package isentropic efficiency metric. This section discusses, in detail, the formulas needed to calculate part-load isentropic efficiency for fixed-speed compressors. DOE notes that certain inputs to these formulas are measured or calculated using ISO 1217:2009, certain sections of which DOE proposes to incorporate by reference. For these inputs, DOE has referenced the specific location within ISO

[26] The isentropic exponent of air has some limited variability with atmospheric conditions. DOE chose a fixed value of 1.400 to align with the EU Lot 31 proposed metric calculations.

1217:2009 where that value or calculation procedure is found. However, complete details on ISO 1217:2009, and DOE's justification for its use in this test procedure, are discussed in section III.D.

As discussed in section III.C.3, part-load package isentropic efficiency is calculated using a weighted average of three load points: 40, 70, and 100 percent of maximum flow rate. The equation for part-load package isentropic efficiency is as follows:

$$\eta_{isen,PL} = \omega_{40\%} \times \eta_{isen,40\%} + \omega_{70\%} \times \eta_{isen,70\%} + \omega_{100\%} \times \eta_{isen,100\%}$$

Eq. 6

Where:

$\eta_{isen,PL}$ = part-load package isentropic efficiency for a variable-speed compressor,

$\eta_{isen,100\%}$ = package isentropic efficiency at full-load operating pressure, as determined in equation 3,

$\eta_{isen,70\%}$ = package isentropic efficiency at 70 percent of full-load actual volume flow rate, as determined in equation 7,

$\eta_{isen,40\%}$ = package isentropic efficiency at 40 percent of full-load actual volume flow rate, as determined in equation 9,

$\omega_{40\%}$ = weighting at 40 percent of full-load actual volume flow rate (0.25), as described in section III.C.3,

$\omega_{70\%}$ = weighting at 70 percent of full-load actual volume flow rate (0.5), as described in section III.C.3, and

$\omega_{100\%}$ = weighting at 100 percent of full-load actual volume flow rate (0.25), as described in section III.C.3.

The equation for full-load package isentropic efficiency is the same as noted in III.C.4, above (equation 3 through equation 5). Package isentropic efficiency at 40 and 70 percent of full-load actual volume flow rate are defined as follows:

$$\eta_{\mathrm{isen},70\%} = \frac{P_{\mathrm{isen},70\%}}{P_{\mathrm{real},70\%}}$$

Eq. 7

Where:

$\eta_{isen,70\%}$ = package isentropic efficiency at 70 percent of maximum flow rate,

$P_{isen,70\%}$ = isentropic power required for compression at 70 percent of full-load actual volume flow rate, as determined in equation 11, and

$P_{real,70\%}$ = packaged compressor power input at 70 percent of full-load actual volume flow rate, as determined from equation 8[27].

$$P_{\mathrm{real},70\%} = K_5 \cdot P_{\mathrm{PR},70\%}$$

[27] The correction factor for the shaft speed (K_4) in section C.4.3.1 of annex C in ISO 1217:2009 is not applicable to this test procedure because the electric motor drive is included in the package, and it is therefore omitted from this equation.

Eq. 8

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009 at a contractual inlet pressure of 100 kPa,[28] and

$P_{PR,70\%}$= packaged compressor power input reading at full-load operating pressure and 70 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

$$\eta_{isen,40\%} = \frac{P_{isen,40\%}}{P_{real,40\%}}$$

Eq. 9

Where:

$\eta_{isen,40\%}$ = package isentropic efficiency at 40 percent of full-load actual volume flow rate,

$P_{isen,40\%}$ = isentropic power required for compression at 40 percent of full-load actual volume flow rate, as determined in equation 12, and

$P_{real,40\%}$ = packaged compressor power input at 40 percent of full-load actual volume flow rate, as determined from equation 10.[29]

[28] The correction factor for inlet pressure uses contractual values for inlet pressure. Since a contractual value is not applicable to this test procedure, a value of 100 kPa from annex F in ISO 1217:2009 is used.

$$P_{real,40\%} = K_5 \cdot P_{PR,40\%}$$

Eq. 10

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009 at a contractual inlet pressure of 100 kPa,[30] and

$P_{PR,40\%}$= packaged compressor power input reading at full-load operating pressure and 40 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

Finally, $P_{isen,70\%}$, and $P_{isen,40\%}$ would then be calculated using values measured at each of the designated rating points, as shown in equations 11 and 12 respectively:

$$P_{isen,70\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right]$$

Eq. 11

[29] The correction factor for the shaft speed (K_4) in section C.4.3.1 of annex C in ISO 1217:2009 is not applicable to this test procedure because the electric motor drive is included in the package, and it is therefore omitted from this equation.
[30] The correction factor for inlet pressure uses contractual values for inlet pressure. Since a contractual value is not applicable to this test procedure, a value of 100 kPa from annex F in ISO 1217:2009 is used.

Where:

$\dot{V}_{1\_m3/s}$ = corrected volume flow rate at 70 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = Atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

p_2 = discharge pressure at 70 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which for the purposes of this test procedure is 1.400.[31]

$$P_{isen,40\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right]$$

Eq. 12

Where:

$\dot{V}_{1\_m3/s}$ = corrected volume flow rate at 40 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = Atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

[31] The isentropic exponent of air has some limited variability with atmospheric conditions. DOE chose a fixed value of 1.400 to align with the EU Lot 31 proposed metric calculations.

p_2 = discharge pressure at 40 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which for the purposes of this test procedure is 1.400.[32]

DOE requests comment on its proposed definition for part-load package isentropic efficiency, and its use as the metric for variable-speed compressors.

D. Test Method

This section discusses DOE's proposal for a test method to measure, in a standardized and reproducible manner, all quantities needed to determine package isentropic efficiency. These quantities are: inlet and discharge pressures, flow rate, and packaged compressor power input at given load point(s). Specifically, DOE proposes to incorporate by reference the test methods contained in certain, applicable sections of ISO 1217:2009 as the basis for the compressors test procedure. However, DOE notes that several modifications and additions to ISO 1217:2009 are required to determine the package isentropic efficiency of applicable compressors and improve the repeatability of ratings. These proposals are discussed in sections III.D.1 and III.D.2.

1. Referenced Industry Test Method

In the Framework Document, DOE noted the need to establish a test method capable of reliably measuring compressor performance for determining compliance with

[32] The isentropic exponent of air has some limited variability with atmospheric conditions. DOE chose a fixed value of 1.400 to align with the EU Lot 31 proposed metric calculations.

energy conservation standards. DOE stated that it was considering two industry standards (ISO 1217:2009 and ISO 5389:2005) as the basis for DOE's compressor test procedure. DOE requested comments from interested parties on the potential use of several test procedures, including ISO 1217:2009, as a basis for the development of a DOE test procedure. (Docket No. EERE-2013-BT-STD-0040, No. 1 at p. 12).

In response to the Framework Document, The Joint Commenters, CAGI, and the CA IOUs all recommended using ISO 1217:2009 for compressor package testing. (CAGI, No. 0009 at p. 3; Joint Comment, No. 0016 at p. 3; and CA IOUs, No. 0018 at p. 3) CAGI further commented during the Framework Public Meeting that it would evaluate ISO 1217:2009 to determine if additional changes were necessary. (CAGI, No. 0040 at p. 92) Ingersoll-Rand cautioned that ISO 1217:2009 may require changes in order to measure package isentropic efficiency but provided no specific recommendations regarding these changes. (Ingersoll-Rand, No. 0040 at p. 90) DOE agrees with Ingersoll-Rand, and DOE has proposed specific methods for calculating package isentropic efficiency, as discussed in sections III.C.4 and III.C.5. DOE's proposal uses the methods and results of ISO 1217:2009 as a basis for their proposed test procedure, but provides additional calculations and provisions that are necessary for determining package isentropic efficiency.

In response to the comments regarding the use of ISO 1217:2009, DOE reviewed ISO 1217:2009 and ultimately determined that it (1) is the most widely used test standard in the compressor industry for evaluating positive displacement compressor performance; and (2) it attempts to define uniform methods for conducting laboratory tests to determine the inlet and discharge pressures, flow rate, and packaged compressor power input at a given load point—all of which are required to calculate part- and full-load package isentropic efficiency (as defined sections III.C.4 and III.C.5). ISO 1217:2009 also contains certain specifications regarding test equipment, instrument accuracy, and test tolerances. However, as discussed previously, DOE notes that several modifications and additions to ISO 1217:2009 are required to determine the package isentropic efficiency of applicable compressors and improve the repeatability and reproducibility of ratings.

Generally, in DOE's view, ISO 1217:2009 is an appropriate industry testing standard for evaluating performance of applicable compressors. However, DOE notes that ISO 1217:2009 is written as a customer acceptance test. As such, DOE believes that several modifications and additions to ISO 1217:2009 are required in order to provide the specificity and repeatability required by DOE. These proposed modifications are discussed in detail in section III.D.2. Furthermore, DOE notes that ISO 1217:2009 provides both "complete" and "simplified" test methods for a variety of compressor categories, only some of which are within the scope of applicability of DOE's proposed test procedure. As such, DOE proposes to incorporate by reference only the sections of ISO 1217:2009 that are relevant to the equipment within the scope of applicability of DOE's proposed test procedure. The specific sections proposed for incorporation, and well as the specific proposed modifications, are discussed further in III.D.2.

Ultimately, by incorporating by reference much of ISO 1217:2009 into the proposed DOE test procedure, DOE believes that the resulting DOE test procedure will remain closely aligned with existing and widely used industry procedures and limit testing burden on manufacturers.

2. Modifications, Additions, and Exclusions to ISO 1217:2009

As discussed previously, DOE believes that certain modifications, additions, and exclusions are necessary to ensure repeatable and reproducible test results and provide measurement methods and testing equipment specifications for the entire scope of compressors that DOE would address as part of this proposal. These specific modifications, additions and exceptions are discussed in the following sections III.D.2.a through III.D.2.i.

a. Sections Not Included in DOE's Incorporation by Reference

While DOE proposes to incorporate by reference certain, applicable sections of ISO 1217:2009 as the basis for its compressor test procedure, DOE notes that the following sections, subsections, and annexes of the standard are not applicable to DOE's regulatory framework:

- Sections 1, 7, 8 and 9, in their entirety;
- Section 6, in its entirety (except subsections 6.2(g), and 6.2(h), which would be incorporated by reference);
- Subsections 5.1, 5.5, 5.7, and 5.8;
- Annexes A, B, D, E, F, and G in their entirety; and
- Sections C.1.2, C.2.1, C.3, C.4.2.2, C.4.3.1 and C.4.5 of Annex C.

Specifically, section 1 of ISO 1217:2009, titled "Scope," discusses the scope of applicability of ISO 1217:2009. However, the scope discussed in section 1 of ISO 1217:2009 does not align with the specific proposed scope of applicability for DOE's test procedure, as established in section III.B of this notice.

Section 7 of ISO 1217:2009 is titled "Uncertainty of measurement" and simply refers the reader to Annex G for information on uncertainty of measurement. Section 7 of ISO 1217:2009 is not called upon by any other sections of ISO 1217:2009 relevant to the testing of compressors within the scope of this rulemaking. Section 8 of ISO 1217:2009 is titled "Comparison of test results with specified values" and discusses how to compare test results with contractually guaranteed performance values. Such methods would not be required for testing and rating compressors in accordance with DOE's proposed test procedure. Furthermore, in section III.G, DOE proposes its own sampling and enforcement criteria for compressors included in the scope of applicability of this proposed test procedure.

Section 9, titled "Test report," contains requirements regarding the generation of a test report. These requirements are not relevant to the testing and rating of compressors in accordance with DOE's proposed procedure. Accordingly, DOE is not proposing to incorporate these sections of ISO 1217:2009 by reference.

Section 6 of ISO 1217:2009 is titled "Test procedures" and discusses procedures for a compressor acceptance test. However, DOE proposes to incorporate by reference much of Annex C to ISO 1217:2009, titled "Simplified acceptance test for electrically driven packaged displacement compressors." Both Section 6 and Annex C of ISO 1217:2009 provide methods to calculate discharge pressure, inlet pressure, flow rate, and packaged compressor power input at a given load point. However, the methods contained in Annex C are more specifically optimized for the categories of compressors within the scope of applicability of this rulemaking, and are more widely used in the compressor industry. As a result, DOE proposes to incorporate by reference the methods prescribed in Annex C to ISO 1217:2009, and not to incorporate by reference section 6 of ISO 1217:2009, with the following exceptions:

- DOE proposes to incorporate by reference sections 6.2(g), and 6.2(h) of ISO 1217:2009, as they contain important testing configuration information that is not supplied in Annex C to ISO 1217:2009.

- DOE proposes not to incorporate by reference sections C.1.2, C.2.1, C.3, C.4.2.2, C.4.3.1 and C.4.5 of Annex C to ISO 1217:2009, as these subsection provide instructions that are not relevant to the testing and rating of compressors in accordance with DOE's proposed procedure.

Subsection 5.1 of ISO 1217:2009 contains general statements related to measuring equipment, methods and accuracy; however, DOE finds most of the statements and instructions in this subsection to be general and ambiguous in nature. To avoid any confusion, DOE proposes not to incorporate by reference subsection 5.1 of ISO

1217:2009. Subsections 5.5 and 5.8 to ISO 1217:2009 provide instructions for how to measure quantities not relevant to DOE proposed test procedures. As a result, DOE proposes not to incorporate by reference subsections 5.5 and 5.8 of ISO 1217:2009. Subsection 5.7 provides instruction for how to measure power and energy; however, this information is also provided in Annex C to ISO 1217:2009. As discussed previously, DOE proposes to use the methods established in Annex C rather than Section 5. Consequently, DOE proposes not to incorporate by reference subsection 5.7 of ISO 1217:2009.

Annex A to ISO 1217:2009, “Acceptance test for liquid-ring compressors;” annex B to ISO 1217:2009, “Simplified acceptance test for bare compressors;” and annex D to ISO 1217:2009, “Simplified acceptance test for internal combustion engine-driven packaged displacement compressors;” are not required for, or applicable to, testing compressors within the proposed scope of this rulemaking. As such, DOE proposes to not incorporate annexes A, B, and D to ISO 1217:2009 by reference.

Annex E to ISO 1217:2009, titled “Acceptance test for electrically driven packaged displacement variable speed drive compressors,” is currently used by CAGI to evaluate variable-speed compressors for their performance verification program. This annex stipulates a specific set of load points and states that a variable-speed compressor should be tested at each load point using the methods established in annex C of ISO 1217:2009. However, the load points identified in annex E are not the same as the variable-speed load points proposed by DOE in section III.C.3. Consequently, it is not necessary for DOE to include annex E within this proposed test procedure, and DOE is not proposing to incorporate annex E to ISO 1217:2009 by reference.

Annex F to ISO 1217:2009 is titled "Reference conditions" and provides informative standard inlet conditions for a compressor test. However, DOE proposes to explicitly provide applicable standard inlet conditions in section III.D.2.c. Annex G to ISO 1217:2009 is not called upon by any other sections of ISO 1217:2009 relevant to the testing compressors within the scope of this rulemaking. As such, DOE proposes to not incorporate annexes F or G to ISO 1217:2009 by reference.

After considering the sections and subsections listed in this section, and based on the reasoning provided, DOE ultimately proposes to incorporate by reference the following sections and subsections of ISO 1217:2009:

- Sections 2, 3, and 4;
- Subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), 6.2(h); and
- Subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C.

DOE requests comment on its proposal to incorporate by reference certain applicable sections of ISO 1217: 2009 as the basis of the DOE test procedure for compressors. DOE requests comment on the proposal not to incorporate by reference specific sections and annexes as explained in this section.

b. Terminology

DOE notes that, although section 3.4.1 of ISO 1217:2009 defines the term "actual volume flow rate," the term "corrected volume flow rate" is used throughout the standard to refer to the same quantity. To clarify, DOE is proposing to use the term "actual volume flow rate" exclusively and to note that, where the ISO 1217:2009 refers to "corrected volume flow rate" the term would be deemed equivalent and synonymous with the term "actual volume flow rate."

c. Testing Conditions

Subsection 6.2 of ISO 1217:2009 specifies test arrangements and accuracy requirements for testing compressors. However, as previously discussed, DOE finds that the information contained in this subsection is not sufficient to produce accurate and repeatable test results. As such DOE proposes to not incorporate the majority of this subsection by reference. Rather, DOE proposes to adopt several requirements regarding the ambient testing conditions and input power characteristics.

Ambient Conditions

DOE notes that section 6.2(d) of ISO 1217:2009 states that "test conditions shall be as close as reasonably possible to the conditions of guarantee…If no inlet conditions have been agreed, then the provisions of Annex F shall apply." Because DOE is proposing to establish a performance test, rather than a customer acceptance test (i.e., there are no applicable conditions of guarantee), DOE proposes to not incorporate section 6.2(d) of ISO 1217:2009 by reference into its proposed test procedure. However, DOE recognizes that ambient conditions may affect test results; as such DOE proposes to specify relevant ambient test conditions as part of this test procedure, rather than rely on specification contained in ISO 1217:2009.

DOE understands that the CAGI Performance Verification Program specifies that testing should occur with an ambient air temperature of 80-90 °F. DOE proposes to adopt this range of ambient air temperature (and specify that the range is inclusive of the endpoints) to remain consistent with current industry practices. DOE also proposes not to require certain ambient condition requirements for inlet pressure or relative humidity, as corrections for differences in these values are accounted for in ISO 1217:2009. Finally, DOE proposes to specify that the inlet of the compressor under test must be open to ambient conditions and intake ambient air during testing.

DOE requests comment regarding the proposed ambient conditions required for testing, and if they are sufficient to produce repeatable and reproducible test results.

Power Supply Characteristics

DOE notes that ISO 1217:2009 does not specify the power supply characteristics required for testing. Because packaged compressor power input is a component of the proposed metric, measuring power is an important element of the test. The characteristics of the power supplied to the compressor will affect the repeatability and reproducibility of the measured packaged compressor power input. As a result, to ensure accurate and repeatable measurement of packaged compressor power input, DOE also proposes to specify nominal characteristics of the power supply. Namely, DOE proposes nominal values for voltage, frequency, voltage unbalance, and total harmonic distortion, as well as tolerances for each of these values that must be maintained at the input terminals to the compressor equipment.

To determine the appropriate power supply characteristics for testing compressors, DOE examined applicable test methods for similar equipment (i.e., equipment typically driven by electric motors and sometimes accompanied with variable frequency drives). DOE reviewed the recently published pumps test procedure final rule, which adopts specific requirements for the voltage, frequency, voltage unbalance, and total harmonic distortion when testing pumps in accordance with the DOE test procedure. These requirements are shown in Table III.4. DOE believes that, because compressors utilize similar electrical equipment (i.e., electric motors and drives) to pumps, such requirements should also apply when testing compressors.

Table III.4 Proposed Power Supply Requirements for Compressors

Characteristic	Tolerance
Voltage	±5 percent of the rated value of the motor
Frequency	±1 percent of the rated value of the motor
Voltage Unbalance	±3 percent of the rated value of the motor
Total Harmonic Distortion	≤12 percent

DOE notes that, as discussed at length in the pumps test procedure final rule, these power supply requirements are generally consistent with the requirements and operating conditions for other, similar commercial equipment (i.e., that operate with electric motors and sometimes variable frequency drives) and with relevant industry test standards. In addition, DOE noted in the January 2016 general pumps test procedure final rule that these requirements are generally available on the national electric power grid and, therefore, not unduly burdensome to conduct. 81 FR 4086 (Jan. 25, 2016). DOE believes the requirements, by extension, would present a similarly low level of burden with respect to compressors.

DOE requests comment on the proposed voltage, frequency, voltage unbalance, and total harmonic distortion requirements when performing a compressor test. Specifically, DOE requests comments on whether these tolerances can be achieved in typical compressor test labs, or whether specialized power supplies or power conditioning equipment would be required.

d. Equipment Configuration

ISO 1217:2009 does not specify how a unit under test should be configured for testing. As a result, DOE proposes to specify how equipment is to be configured to ensure repeatable results when conducting the DOE test procedure.

The proposed definition for an air compressor includes ancillary equipment, and therefore DOE proposes to specify that all ancillary equipment that is distributed in commerce with the compressor must be present and installed for all tests.

The proposed definition for an air compressor also specifies that the air compressor has an inlet open to the atmosphere or other source of air. In addition, DOE is proposing ambient conditions for testing. Because an air compressor may have an inlet open to an “other source of air,” DOE proposes to specify that the inlet of the compressor under test must be open to the atmosphere and take in ambient air for all tests.

DOE requests comment on the proposed equipment configuration that the inlet of the air compressor under test be open to the atmosphere and take in ambient air, and whether all air compressors can be configured and tested in this manner.

Finally, DOE notes that air compressors often require setup prior to testing. DOE proposes that a unit under test must be set up according to all manufacturer instructions for normal operation. Instructions from the manufacturer may include instructions on verifying oil levels and/or filling the unit with oil for lubrication, checking and connecting loose internal electrical connections, ensuring the bottom of the unit is closed from ambient air and in contact with the floor as intended, or installing forklift cover holes.

DOE requests comment on the proposed requirements for equipment configuration.

e. Data Collection and Sampling

To ensure the repeatability of test data and results, the DOE compressor test procedure should provide instructions about how to sample and collect data at each load point such that the collected data is taken at stabilized conditions that accurately and precisely represent the performance of the compressor at that load point. Section 6.2(i) of ISO 1217:2009 states that "before readings are taken, the compressor shall be run long enough to ensure that steady-state conditions are reached so that no systematic changes occur in the instrument readings during the test." However, ISO 1217:2009 does not clearly define, in a repeatable way, what steady-state conditions are, and how a test operator would know definitively that steady-state has been reached. As a result, DOE proposes to require that measurements be taken at steady-state conditions, which are achieved when the difference between two consecutive, unique, power measurements, taken at least 10 seconds apart and no more than 60 seconds apart and measured per section C.2.4 of Annex C to ISO 1217:2009, is less than or equal to 300 watts. DOE believes that this requirement is sufficient to ensure the measurement is accurate and precise for either manually or digitally recorded data points. Additionally, DOE understands that a similar 300-watt stability requirement is currently the standard industry practice.

With regards to data sampling and frequency, section 6.2(k) of ISO 1217:2009 states that "for each load, a sufficient number of readings shall be taken to indicate that steady-state conditions have been reached. The number of readings and the intervals shall be chosen to obtain the required accuracy." Due to the lack of specificity regarding the number and interval of data points required, DOE proposes to not incorporate section 6.2(k) of ISO 1217:2009 by reference into its proposed test procedure. Instead, DOE proposes that formal data recordings used to determine package isentropic efficiency, package specific power, and pressure ratio consist of at least 16 unique measurements, collected over a minimum time of 15 minutes. Each consecutive measurement must be spaced no more than 60 seconds apart, and not less than 10 seconds apart. To ensure that the compressor remains at steady state throughout the test, the difference in packaged compressor power input between the maximum and minimum measurement during the 15-minute data recording time period must be less than or equal to 300 watts, as measured per section C.2.4 of Annex C to ISO 1217:2009. DOE proposes that all the unique measurements taken in each 15-minute data recording time period must meet the requirements in this section; if one or more measurements in each data recording time period do not meet the requirements, then a new data recording of at least 16 new unique measurements collected over a minimum time of 15 minutes must be performed.

DOE requests comment regarding the proposed data collection requirements.

f. Allowable Deviations from Specified Load Points

DOE notes that Tables C.1 and C.2 of Annex C to ISO 1217:2009 specify maximum deviations from specified values of discharge pressures during an acceptance test and maximum deviations in volume flow rate at specified conditions permissible at test, respectively. DOE proposes to specify that when performing the DOE test procedure for package isentropic efficiency, the values listed in Tables C.1 and C.2 of Annex C of ISO 1217:2009 would serve as the maximum allowable deviations from the discharge pressure and volume flow rate load points specified in the proposed test procedure.[33]

DOE requests comment on the allowable deviations in Tables C.1 and C.2 of Annex C of ISO 1217:2009. Specifically, DOE requests comment on whether air compressors are able to control discharge pressure and volume flow rate with more precision than as specified from values in Tables C.1 and C.2 of Annex C of ISO 1217:2009.

[33] DOE notes that Table C.2 of Annex C of ISO 1217:2009 uses the term "volume flow rate." For the purposes of the proposed DOE test procedure, the term "volume flow rate" in Table C.2 will be considered synonymous with the "actual volume flow rate" of the compressor under test.

g. Calculations and Rounding

DOE notes that ISO 1217:2009 does not specify how to round values when performing calculations or making representations. DOE recognizes that the order and manner in which values are rounded can affect the resulting value, and, for consistency, it is important that all represented values of package isentropic efficiency, package specific power, actual volume flow rate, and full-load operating pressure be represented consistently across the compressor industry. DOE proposes to require that all calculations be performed with the raw measured data, to ensure accuracy. DOE also proposes that the package isentropic efficiency be rounded and represented to the nearest 0.001[34], package specific power be rounded and represented to the nearest 0.01 kilowatt per 100 cubic feet per minute, pressure ratio be rounded and represented to the nearest 0.1, actual volume flow rate be rounded and represented to the nearest 0.1 acfm, and full-load operating pressure be rounded and represented to the nearest 1 psig.

h. Measurement Equipment

Packaged Compressor Power Input.

DOE reviewed section C.2.4 of annex C to ISO 1217:2009 "Measurement of packaged compressor power input" and found that it did not contain clear and explicit tolerance requirements for equipment used to measure the power supplied to the compressor under test. In the absence of tolerance requirements established by the compressor industry, DOE evaluated accuracy requirements for electrical measurement equipment for similar commercial and industrial equipment – specifically, pumps. DOE

[34] DOE's proposal is consistent with CAGI's current performance verification datasheet practice, which expresses energy consumption to three significant digits.

considers commercial and industrial pumps to be similar and relevant, as these pumps are typically driven by the same electric motors and variable-frequency drives (if present) as compressors and have similar power supply requirements.

In the pumps test procedure final rule, DOE adopted specific requirements for electrical measurement equipment used to measure input power to the motor, continuous controls, or non-continuous controls. Specifically, DOE specified that the electrical measurement equipment in such cases must be capable of measuring true RMS current, true RMS voltage, and real power up to at least the 40th harmonic of fundamental supply source frequency and have an accuracy level of ±2.0 percent of the measured value when measured at the fundamental supply source frequency. DOE noted that such characteristics and requirements are consistent with other, similar industry test standards for applicable motors and controls and are necessary for determining compliance with the pump power supply requirements, which are the same as those proposed in section III.D.2.c for compressors.

DOE notes that several interested parties commented throughout the pumps rulemaking that such measurement equipment was necessary due to the potential impact of the continuous control on line harmonics and other equipment on the circuit. (Docket No. EERE-2011-BT-STD-0031, CA IOUs, Framework public meeting transcript No. 19 at p. 236; Docket No. EERE-2011-BT-STD-0031, HI, No. 25 at p. 35; Docket No. EERE-2013-BT-TP-0055, AHRI, No. 11 at pp. 1–2) AHRI also indicated that any harmonics in the power system can affect the measured performance of the pump when tested with a motor or motor and continuous or non-continuous control. (Docket No.

EERE-2013-BT-TP-0055, AHRI, No. 11 at pp. 1–2) DOE believes that, similarly, such equipment is necessary to accurately measure the input power to the compressors that would be subject to this test procedure.

DOE also recognizes that current and voltage instrument transformers can be used in conjunction with electrical measurement equipment to measure current and voltage. Usage of instrument transformers can introduce additional losses and errors to the measurement system. Section C.2.4 of annex C to ISO 1217:2009 recognizes this potential for losses and errors and states that "current and voltage transformers shall be chosen to operate as near to their rated loads as possible so that their ratio error is minimized." However, this section does not specify precisely how to combine the individual errors of each transformer to determine the combined accuracy of the measurement system. To clarify this ambiguity, DOE reviewed applicable industry test procedures related to electrical power measurement. Section C.4.1 of AHRI 1210-2011 indicates that combined accuracy should be calculated by multiplying the accuracies of individual instruments. In contrast, section 5.7.2 of CSA C838-2013 indicates that if all components of the power measuring system cannot be calibrated together as a system, the total error must be calculated from the square root of the sum of the squares of all the errors. DOE understands that it is more accurate to combine independent accuracies (i.e., uncertainties or errors) by summing them in quadrature.[35] DOE therefore proposes to use

[35] National Institute of Standards and Technology (NIST) Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results (http://physics.nist.gov/Pubs/guidelines/sec5.html, accessed September 8, 2015).

the root sum of squares to calculate the combined accuracy of multiple instruments used in a single measurement, consistent with conventional error propagation methods.[36]

Therefore, in this NOPR, DOE proposes that the electrical measurement equipment used when measuring the input power to the compressor must be capable of measuring true RMS current, true RMS voltage, and real power up to at least the 40th harmonic of fundamental supply source frequency and have a combined instrument accuracy level of ±2.0 percent of the measured value when measured at the fundamental supply source frequency. Combined instrument accuracy would be calculated by summing the individual accuracies in quadrature.

DOE requests comment regarding the proposed packaged compressor power input measurement equipment requirements.

Pressure Measurement.

DOE reviewed section 5.2 of ISO 1217:2009, "Measurement of Pressure," and concluded that certain language contained in this section requires clarification in order to achieve unambiguous, reproducible, and repeatable pressure measurements. Specifically, section 5.2.1 of ISO 1217:2009 states that "Connecting piping shall be leak-free, as short as possible, of sufficient diameter and arranged so as to avoid blockage by dirt or condensed liquid." While DOE recognizes the intent of this instruction, DOE prefers to

[36] DOE notes that section G.2.5.2 of Annex G to ISO 1217 also directs uncertainties to be summed in quadrature. However, Annex G to ISO 1217:2009 is not directly referenced by the applicable power measurement section of ISO 1217:2009 (section C.2.4 of Annex C), and therefore DOE is not proposing to incorporate Annex G by reference.

provide quantitative instructions and measurements to determine if equipment is "leak-free and of sufficient diameter" and a quantitative definition of the term "short as possible." Additionally, DOE finds the following terms and instruction to be ambiguous: "tightness shall be tested and all leaks eliminated;" "mounted so that they are not susceptible to disturbing vibrations;" "pressure waves in the inlet pipe or the discharge pipe are found to exceed 10 % of the prevailing average absolute pressure, the piping installation shall be corrected before proceeding with the test;" "pressure and temperature conditions similar to those prevailing during the test;" "shall be corrected for the gravitational acceleration at the location of the instrument;" "a receiver with inlet throttling shall be provided between the pressure tap and the instrument;" and "Oscillations of gauges shall not be reduced by throttling with a valve placed before the instrument, however, a restricting orifice may be used."

In an effort to address some of those ambiguities, DOE proposes several requirements related to measurement of pressure in this test procedure NOPR. First, DOE proposes to require that discharge piping must be equal in diameter to the discharge orifice of the compressor package, and extend in length a distance of at least 15 times that diameter with no transitions or turns. Second, DOE proposes to require that the pressure tap be placed in the discharge pipe, between 2" and 6" away from the discharge, at the highest point of the cross section of the pipe.

DOE requests comment to help clarify these ambiguities contained in section 5.2.1 of ISO 1217:2009. Specifically, DOE requests potential quantitative explanations and instructions related to the following items: pressure tap installation locations;

methods to verify "leak-free" pipe connections; "short as possible" and of "sufficient diameter"; testing "tightness"; mounting instruments so that the unit is "not susceptible to disturbing vibrations"; how and where to test for "pressure waves" and how the piping installation can be "corrected;" how to calibrate transmitters and gauges under "pressure and temperature conditions similar to those prevailing during the test"; how to correct dead-weight gauges for "gravitational acceleration at the location of the instrument"; where to install "a receiver with inlet throttling" to correct for flow pulsations; and how a restricting orifice may be used to reduce oscillation of gauges. Finally, DOE requests comment on its proposals regarding discharge piping and pressure taps.

Additionally DOE proposes to clarify that any measurement of pressure used in a calculation of another variable (e.g., actual volume flow rate) must also meet all accuracy and measurement requirements of section 5.2 of ISO 1217:2009.

Temperature Measurement.

DOE reviewed section 5.3 of ISO 1217:2009 and proposes that any measurement of temperature meet the requirements of this section. Additionally, DOE notes that any measurement of temperature used in a calculation of another variable (e.g., actual volume flow rate) must also meet all accuracy and measurement requirements of section 5.3 of ISO 1217:2009.

Density Measurement.

DOE reviewed ISO 1217:2009 and notes that it does not provide accuracy requirements for measurement of density, which may be measured to support the calculation of actual volume flow rate. In the absence of accuracy requirements established in ISO 1217:2009, DOE proposes any measurement of density must have an accuracy of ±1.0 percent of the measured value.

DOE requests comment regarding the proposed density measurement equipment requirements.

i. Determination of Maximum Full-Flow Operating Pressure, Full-Load Operating Pressure, and Full-Load Actual Volume Flow rate

As part of this test procedure, DOE proposes to specify the load points for testing based on the actual volume flow rate at full-load operating pressure of the unit (full-load actual volume flow rate as discussed previously in section III.C.2). However, ISO 1217:2009 does not provide a method to determine full-load operating pressure of the tested unit. Rather, ISO 1217:2009 relies on manufacturer-specified full-load operating pressures. Similarly, CAGI specifies a “maximum full flow operating pressure,” which is explained on the CAGI data sheets as “the maximum pressure attainable at full flow, usually the unload pressure setting for load/no load control or the maximum pressure attainable before capacity control begins.” CAGI data sheets also specify a “full load operating pressure,” which is defined as “the operating pressure at which the capacity and electrical consumption were measured for this data sheet.” The CAGI specifications demonstrate that compressor manufacturers typically make performance representations at this nominal full-load operating pressure condition, rather than at the actual tested maximum operating pressure of the unit.

In order to have a reproducible and repeatable test procedure and ensure comparability of test results, DOE prefers to rely on objective rating point(s) determined through repeatable testing methods, as opposed to ”nominal” values or arbitrarily selected rating conditions. Doing so allows for accurate comparison between compressors from different manufacturers and ensures reproducible testing for all equipment. However, DOE recognizes that testing at the actual tested maximum full-flow operating pressure may increase variability in test results and may be a less representative rating condition, as it is representative of the unload pressure just before the compressor shuts off. DOE also acknowledges that manufacturers may design their compressors to operate optimally at a nominal full-load operating pressure slightly less than the tested maximum. Further, DOE recognizes that the preponderance of manufacturer test data and performance information, such as CAGI performance data, exists at such nominal full-load operating pressure conditions and it would be extremely burdensome to retest all compressors to evaluate performance at the maximum full-load operating pressure instead of the nominal full-load operating pressure.

Based on all of these considerations, DOE developed a quantitative and standardized method to determine the full-load operating pressure, while still preserving sufficient flexibility to allow most manufacturers to select an appropriate and representative full-load operating pressure within a narrow range. That is, DOE proposes to include a specific test method to determine the maximum full-flow operating pressure of the equipment, which is representative of the maximum discharge pressure at full-flow (i.e., the maximum discharge pressure attainable before capacity control begins, including unloading for load/no load controls), as described in this section. DOE proposes to allow manufacturers to specify the full-load operating pressure that would be used for subsequent testing and determination of full-load actual volume flow rate, specific power, and package isentropic efficiency, provided the specified value is greater than or equal to 90 percent and less than or equal to 100 percent of the maximum full-flow operating pressure. That is, DOE would allow manufacturers to self-declare the full-load operating pressure as between 90 and 100 percent of the measured maximum full-flow operating pressure. The full-load operating pressure would then be used to determine the full-load actual volume flow rate, specific power, and package isentropic efficiency values for that compressor model.

DOE reviewed CAGI performance data to determine an appropriate range for manufacturer self-declared full-load operating pressure, based on maximum full-flow operating pressure. DOE found that 94 percent of units had a full-load operating pressure in the proposed range of 90 to 100 percent of the maximum full-flow operating pressure. Additionally, DOE found that 59 percent of units had a full-load operating pressure within a narrower range of 95 to 100 percent of the maximum full-flow operating pressure.

DOE requests comment on the proposal to allow manufacturers to self-declare the full-load operating pressure between 90 and 100 percent of the measured maximum full-flow operating pressure, and whether a smaller or larger range should be used.

Therefore, DOE proposes a test procedure to determine maximum full-flow operating pressure for both fixed- and variable-speed compressors. As no industry standard method exists, the method DOE proposes to determine maximum full-flow operating pressure is based on DOE's current understanding of typical compressor operation.

DOE proposes that, if units are distributed in commerce by the manufacturer equipped with any mechanism to adjust the maximum discharge pressure limit, to adjust this mechanism to the maximum pressure allowed for normal operation, according to the manufacturer's operating instructions for these mechanisms. Mechanisms to adjust discharge pressure may include, but are not limited to, onboard digital or analog controls and user-adjustable inlet valves.

DOE proposes that all tested discharge pressures must be within the manufacturer's specified safe operating range of the compressor. Specifically, DOE proposes that the test must not violate any manufacturer-provided motor-operational guidelines for normal use, including any restriction on instantaneous and continuous input power draw and output shaft power (e.g., electric rating and service factor limits).

DOE also proposes to require that the unit be tested at the maximum driver speed throughout the determination of maximum full-flow operating pressure and full-load operating pressure. For variable-speed compressors, this means that no speed reduction is allowed during testing to determine maximum full-flow operating pressure; speed reduction is still allowed when conducting the remainder of the test procedure to determine package isentropic efficiency, package specific power, and other relevant parameters at the load points specified in section III.C.3. If the unit being tested is a fixed-speed compressor with a multi-speed driver, then all testing would occur at the maximum driver operating speed.

DOE proposes measuring discharge pressure according to the methods described in section 5.2 of ISO 1217:2009; compressor discharge pressure would be expressed in pounds per square inch, gauge ("psig"), in reference to ambient conditions, and reported to the nearest integer. Targeted discharge pressure test points would be specified in integer values only; and maximum allowable measured deviation from the targeted discharge pressure at each load point would be ±1 psig. DOE notes that the ±1 psig deviation tolerance established for this test method differs from, and is typically more stringent than, the discharge pressure deviation tolerances specified in the tests for full-load and part-load isentropic efficiency that are discussed in sections III.C.4 and III.C.5. However, this method requires discharge pressure to be measured in increments of 2 psig, and as a result, a fixed tolerance of ±1 psig is the largest practical tolerance that can still effectively differentiate the discrete pressure test point increments.

DOE proposes that data recording (at each tested point) be conducted under steady-state conditions, which are achieved when the difference between two consecutive, unique, packaged compressor power input reading measurements, taken at a minimum of 10 seconds apart and measured per section C.2.4 of Annex C to ISO 1217:2009, is equal to or less than 300 watts.

For the test methods discussed in this section, DOE proposes that each data recording consist of a minimum of two unique measurements collected at a minimum of

10 seconds apart, and that the unique measurements be averaged. DOE also proposes that each consecutive measurement meet the stabilization requirement discussed in the previous paragraph. Finally, DOE notes that the data recording requirements proposed in this paragraph differ from those specified in the tests for full-load and part-load isentropic efficiency that are discussed in sections III.C.4 and III.C.5. DOE believes that two unique measurements, collected at a minimum of 10 seconds apart, are sufficient to characterize discharge pressure and actual volume flow rate, while the more burdensome 16 unique measurements, collected over a minimum time of 15 minutes, is required to sufficiently characterize compressor input power and ultimately isentropic efficiency.

DOE proposes that the unit under test shall be set up so that back-pressure on the unit can be adjusted (e.g., by valves) incrementally, causing the measured discharge pressure to change, until the compressor is in an unloaded condition. DOE proposes to consider a unit to be in an unloaded condition if capacity controls on the unit automatically reduce the actual volume flow rate from the compressor (e.g., shutting the motor off, or unloading by adjusting valves).

As explained in section III.B.6, maximum full-flow operating pressure is defined conceptually as the maximum discharge pressure at which a compressor is capable of operating. Consequently, the practical goal of this method is to identify the maximum achievable discharge pressure before capacity controls begin. This method achieves this goal by increasing the discharge pressure by increments of 2 psig, by adjusting the system back-pressure, while the unit is operating at full-speed until the unit goes into an unloaded condition.

DOE proposes to begin the test method by adjusting the system back-pressure to 90 percent of the certified maximum full-flow operating pressure (rounded to the nearest integer), or to 90 percent of an advertised or known maximum full-flow operating pressure (rounded to the nearest integer) if there is no certified value, or to 75 psig if there is no advertised or known value. DOE chose 75 psig as a potential starting discharge pressure because it was the lowest full-load operating pressure advertised of all available CAGI performance data. DOE propose to then allow the unit to remain at this setting for 15 minutes to allow the unit to thermally stabilize. This stabilization period allows time for elements within the unit under test to reach intended operating conditions (e.g., lubricant temperature, and thermal expansion of compression element). After this stabilization period, measurements for discharge pressure and actual volume flow rate are taken, as specified in this section.

DOE proposes to then increase discharge pressure of the system (by adjusting the back-pressure of the system) by 2 psig, and allow the unit to remain at this setting for 2 minutes. The specified two minute time period is to allow time for the unit to reach steady-state and to ensure that the unit will not enter an unloaded condition, which may not occur immediately after increasing the discharge pressure. After 2 minutes, if the unit is not in an unloaded condition, measurements for discharge pressure and actual volume flow rate are taken, as specified in this section. DOE proposes to then iteratively increase discharge pressure in increments of 2 psig, allow the compressor to stabilize, and then record the discharge pressure and actual volume flow rate, until the unit reaches an unloaded condition. The maximum discharge pressure recorded over all the test points that does not initiate the compressor capacity controls is the maximum full-flow operating pressure.

As described previously the representative value of full-load operating pressure would then be determined, by the manufacturer, as a value greater than or equal to 90 and less than or equal to 100 percent of the maximum full-flow operating pressure and the full-load actual volume flow rate would be the resultant actual volume flow rate measured at the full-load operating pressure.

DOE requests comment on the proposed method for determining maximum full-flow operating pressure, full-load operating pressure, and full-load actual volume flow rate of a compressor.

DOE requests comment regarding whether any more specific instructions would be required to determine the maximum full-flow operating pressure for variable-speed compressors in addition to the proposal that testing is to be conducted at maximum speed, and no speed reduction is allowed during the test.

E. Definition of Basic Model

In the course of regulating products and equipment, DOE has developed the concept of a basic model to allow manufacturers to group similar equipment to minimize testing burden, provided all representations regarding the energy use of compressors within that basic model are identical and based on the most consumptive unit. See 76 FR

12422, 12423 (Mar. 7, 2011).[37] In that rulemaking, DOE established that manufacturers may elect to group similar individual models within the same equipment class into the same basic model to reduce testing burden, provided all representations regarding the energy use of individual models within that basic model are identical and based on the most consumptive unit. See 76 FR 12422, 12423 (Mar. 7, 2011). However, DOE notes that manufacturers make the decision to group models together with the understanding that there is increased risk associated with such model consolidation due to the potential for an expanded impact from a finding of noncompliance. Consolidation of models within a single basic model results in such increased risk because DOE compliance on a basic model basis. Id.

In keeping with this practice, in this rulemaking DOE proposes a definition of basic model for compressors that defines the compressor models on which manufacturers must conduct testing to demonstrate compliance with any future energy conservation standard for compressors, while still enabling manufacturers to group individual models to reduce the burden of testing. For this rulemaking, DOE proposes to establish a definition of basic model that is similar to other commercial and industrial equipment. Specifically, DOE proposes to define a compressor basic model to include all units of a class of compressors manufactured by one manufacturer, having the same primary energy

[37] These provisions allow manufacturers to group individual models with essentially identical, but not exactly the same, energy performance characteristics into a basic model to reduce testing burden. Under DOE's certification requirements, all the individual models within a basic model identified in a certification report as being the same basic model must have the same certified efficiency rating and use the same test data underlying the certified rating. The Compliance Certification and Enforcement final rule also establishes that the efficiency rating of a basic model must be based on the least efficient or most energy consuming individual model (i.e., put another way, all individual models within a basic model must be at least as energy efficient as the certified rating). 76 FR at 12428-29 (March 7, 2011).

source, and having essentially identical electrical, physical, and functional (or pneumatic) characteristics that affect energy consumption and energy efficiency. DOE notes that the requirement of "essentially identical electrical…characteristics" means that models with different compressor motor nominal horsepower ratings must be classified as separate basic models.

Furthermore, DOE is aware that identical bare compressor, mechanical equipment, and driver combinations may be distributed in commerce with a variety of ancillary equipment, in a variety of configurations, depending on customer requirements. If these variations in ancillary equipment impact the energy use or energy efficiency characteristics of the compressor, then each variation would typically constitute a different basic model. However, as discussed previously, manufacturers may elect to group individual models of compressors into the same basic model to reduce testing burden, provided all representations regarding the energy use of individual models within that basic model are identical and based on the energy performance of most consumptive unit, except that individual models cannot be grouped to span equipment classes or compressor motor nominal horsepower.

DOE requests comment on the proposed definition of a basic model for compressors.

F. Representations of Energy Use and Energy Efficiency

As noted previously, manufacturers of any compressors within the proposed scope of applicability of this rulemaking would be required to use the test procedure established through this rulemaking, if adopted, when determining the represented efficiency or energy use of their equipment. Specifically, 42 U.S.C. 6314(d) requires that "no manufacturer…may make any representation…respecting the energy consumption of such equipment or cost of energy consumed by such equipment, unless such equipment has been tested in accordance with such test procedure and such representation fairly discloses the results of such testing."

DOE is proposing a test procedure for compressors that would provide a method to calculate full-load and part-load isentropic efficiency for fixed-speed and variable-speed compressors, respectively. As such, and consistent with EPCA, DOE proposes that, beginning 180 days after the publication in the Federal Register of any final rule adopting a final test procedure for compressors, all representations of full-load and part-load isentropic efficiency of applicable compressors must be made in accordance with the adopted test procedure. DOE notes that representations include those to DOE as well as any other representations, including those made on the equipment packaging or in marketing materials.

However, with respect to representations of compressor performance, generally, DOE understands that manufacturers often make representations (graphically or in numerical form) of various metrics, including, for example, package specific power at various load points, actual volume flow rate at various load points, and discharge pressure. DOE does not propose to limit the type of representations manufacturers may make with regard to their equipment performance. However, DOE proposes to require that such values be generated using methods consistent with the DOE test procedure.

Specifically, DOE proposes that any representations of $\eta_{isen,FL}$ and $\eta_{isen,PL,}$ as defined in section III.C, must be made according to the DOE test procedure. Furthermore, DOE proposes that the parameters $\eta_{isen,40}$ and $\eta_{isen,70}$, as precursors to the final part-load isentropic efficiency metric, $\eta_{isen,PL}$, must be generated based on the same data, applicable test procedure provisions, and sampling plans.

Additionally, DOE proposes that any representations of the full-load actual volume flow rate, full-load operating pressure, or pressure ratio also must be measured according to the DOE test procedure and sampling plans. DOE notes that these values are key characteristics of compressor performance and are used to determine how to apply the proposed test procedure and the scope of the proposed test procedure to certain compressors. In addition, DOE notes that the attainable efficiency of compressors varies with volume flow rate (i.e., compressors with lower flow rates typically achieve lower efficiencies than compressors with higher flow rates). Consequently, DOE believes that accurate, reproducible, and repeatable representations of these metrics would lead to more meaningful, valuable, and comparable metrics for customers and end-users of this equipment.

DOE understands that, for variable-speed compressors, manufacturers often make representations (graphically or in numerical form) of package isentropic efficiency and package specific power as functions of flow rate or rotational speed. DOE proposes to allow manufacturers to continue making these representations. However, DOE notes that graphical or numerical representations of package isentropic efficiency or package specific power at 40, 70, and 100 percent of the full-load actual volume flow rate must represent values measured in accordance with the DOE test procedure. DOE also notes that graphical or numerical representations of these metrics at any other load points must be generated using methods consistent with the DOE test procedure.

DOE requests comment on its proposal regarding applicable representations of energy and non-energy metrics for compressors.

DOE requests comment on any additional metrics that manufacturers often use when making representations of compressor energy use or efficiency.

G. Sampling Plans for Tested Data and AEDMs

DOE must provide uniform methods for manufacturers to determine representative values of energy- and non-energy-related metrics, for each basic model. See 42 U.S.C. 6314(a)(2). These representative values are used when making public representations (as discussed in section III.F) and when determining compliance with prescribed energy conservation standards. DOE proposes that manufacturers may use either a statistical sampling plan of tested data, in accordance with proposed section 10 CFR 429.61, or an alternative efficiency determination method (AEDM) in accordance with proposed amendments to section 10 CFR 429.70. The following two sections discuss sampling plans and AEDMs.

1. Statistical Sampling Plan

DOE provides, in subpart B to 10 CFR part 429, sampling plans for all covered equipment. As mentioned previously, the purpose of a statistical sampling plan is to provide a method to determine a representative value of energy- and non-energy-related metrics, for each basic model. For compressors, DOE proposes to adopt statistical sampling plans similar to those used for other commercial and industrial equipment, such as pumps, as DOE believes that the variations in testing experienced in other mechanical commercial equipment would be similar to compressors. These requirements would be added in a new section 10 CFR 429.61.

Under this proposal, for purposes of certification testing, the determination that a basic model complies with the applicable energy conservation standard would be based on testing conducted using the proposed DOE test procedure and sampling plan. The general sampling requirement currently applicable to all covered products and equipment provides that a sample of sufficient size must be randomly selected and tested to ensure compliance and that, unless otherwise specified, a minimum of two units must be tested to certify a basic model as compliant. 10 CFR 429.11(b)

DOE proposes to apply this same minimum sample size requirement to compressors. Thus, if a statistical sampling plan is used, DOE proposes that a sample of sufficient size be selected to ensure compliance and that at least two units must be tested to determine the representative values of applicable metrics for each basic model. Manufacturers may need to test a sample of more than two units depending on the variability of their sample, as provided by the statistical sampling plan. Specifically, DOE proposes to establish sampling plans for the following energy and non-energy metrics:

- Full-load package isentropic efficiency (energy metric),
- Part-load package isentropic efficiency (energy metric),
- Package specific power (energy metric),
- Full-load actual volume flow rate (non-energy metric),
- Full-load operating pressure (non-energy metric), and
- Pressure ratio (non-energy metric).

The details of the sampling plan vary based on whether the metric is an energy metric or a non-energy metric. For the energy metrics, DOE employs a statistical process to account for variability in testing and manufacture, as is done with most other covered products and equipment. For many other types of commercial and industrial equipment, such as pumps, DOE has adopted an upper confidence limit (UCL) and lower confidence limit (LCL) of 0.95; which are divided by a de-rating factor of 1.05 and 0.95, respectively. DOE believes that compressors would realize similar performance variability to such other commercial and industrial equipment. Therefore, DOE proposes to adopt a confidence limit of 0.95 and a de-rating factor of 0.95 for package isentropic efficiency, for compressors as part of this test procedure.

For non-energy metrics and package specific power (an optional energy metric) DOE proposes that the represented value be the arithmetic mean of the measured value for each unit. DOE believes this more simplified approach is appropriate, since such values are not used to determine compliance of the basic model and, therefore, accounting for variability and allowing for conservative ratings is not as important. The proposed sampling details for each metric are discussed in the following subsections.

DOE proposes the following sampling plan provisions be incorporated into new 10 CFR 429.61:

Part- or Full-Load Package Isentropic Efficiency

For each basic model of compressor selected for testing, a sample of sufficient size must be randomly selected and tested to ensure that any value of the full- or part-load package isentropic efficiency or other measure of energy consumption of a basic model for which customers would favor higher values is less than or equal to the lower of the following two values:

(1) The mean of the sample, where:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

and $\bar{x}$ is the sample mean; n is the number of samples; and x_i is the measured value for the i^{th} sample;

(2) The lower 95 percent confidence limit (LCL) of the true mean divided by 0.95, where:

$$LCL = \bar{x} - t_{0.95}\left(\frac{s}{\sqrt{n}}\right)$$

and $\bar{x}$ is the sample mean; s is the sample standard deviation; n is the number of samples; and $t_{0.95}$ is the t statistic for a 95 percent one-tailed confidence interval with n–1 degrees of freedom (from appendix A of subpart B).

In addition, DOE also allows for determination of package isentropic efficiency through application of an AEDM, as discussed in section III.G.1.b.

Package Specific Power

The representative value of package specific power of a basic model must be either the mean of the package specific power measured for each tested unit, or as determined through application of an AEDM pursuant to the requirements proposed in section III.G.1.b.

Full-Load Actual Volume Flow Rate

The representative value of full-load actual volume flow rate of a basic model must be either the mean of the full-load actual volume flow rate measured for each tested unit, or as determined through application of an AEDM pursuant to the requirements proposed in section III.G.1.b.

Full-Load Operating Pressure

The representative value of full-load operating pressure of a basic model must be either the mean of the full-load operating pressure measured for each tested unit, or as determined through application of an AEDM pursuant to the requirements proposed in section III.G.1.b.

Pressure Ratio

The representative value of the pressure ratio of a basic model must be either the mean of the pressure ratio for each tested unit, or as determined through application of an AEDM pursuant to the requirements proposed in section III.G.1.b.

DOE requests comment on the proposed sampling plan for certification of compressor models.

b. Records Retention Requirements

Consistent with provisions for other commercial and industrial equipment, DOE notes the applicability of certain requirements regarding retention of certain information related to the testing and certification of compressors, which are detailed under 10 CFR 429.71. Generally, manufacturers must establish, maintain, and retain certification and test information, including underlying test data for all certification testing for two years from date on which the compressor is discontinued in commerce.

2. Alternative Efficiency Determination Methods

a. Background

Pursuant to the requirements of 10 CFR 429.70, DOE may permit use of an alternative efficiency determination method in lieu of testing for equipment for which testing burden may be considerable and for which performance may be well predicted by such alternative methods. Although specific requirements vary by product or equipment, use of an AEDM entails development of a mathematical model that estimates energy efficiency or energy consumption characteristics of the basic model, as would be measured by the applicable DOE test procedure. The AEDM must be based on engineering or statistical analysis, computer simulation or modeling, or other analytic evaluation of performance data. A manufacturer must perform validation of an AEDM by demonstrating that performance, as predicted by the AEDM, is in agreement with performance as measured by actual testing in accordance with the applicable DOE test procedure. The validation procedure and requirements, including the statistical tolerance, number of basic models, and number of units tested vary by product.

Once developed, an AEDM may be used to certify performance of untested basic models in lieu of physical testing. However, use of an AEDM for any basic model is always at the option of the manufacturer. One potential advantage of AEDM use is that it may free a manufacturer from the burden of physical testing. One potential risk is that the AEDM may not perfectly predict performance, and the manufacturer could be found responsible for having an invalid rating for the equipment in question or for having distributed a noncompliant basic model of compressor. The manufacturer, by using an AEDM, bears the responsibility and risk of the validity of the ratings.

During confidential interviews, several manufacturers noted that testing compressors is, in fact, costly and complex, and that in at least some cases, compressor performance could be reliably extrapolated using modeling. Therefore, in this NOPR, DOE proposes to accommodate the application of AEDMs to determine performance ratings for compressors and proposes regulatory language that is consistent with most other commercial and industrial equipment that have AEDM provisions. The specific details are discussed in sections III.G.2.b through III.G.2.e.

b. Basic Criteria any AEDM must Satisfy

A manufacturer may not use an AEDM to determine the values of metrics unless the following three criteria are met:

1) The AEDM is derived from a mathematical model that estimates the energy efficiency or energy consumption characteristics of the basic model as measured by the applicable DOE test procedure;
2) The AEDM is based on engineering or statistical analysis, computer simulation or modeling, or other analytic evaluation of performance data; and
3) The manufacturer has validated the AEDM, in accordance with the applicable validation requirements for such equipment (discussed in section III.G.2.c of this notice).

c. Validation

Validation is the process by which a manufacturer demonstrates that an AEDM meets DOE's requirements for use as a certification tool by physically testing a certain number and style of compressor models and comparing the test results to the output of the AEDM. Before using an AEDM, a manufacturer must validate the AEDM's accuracy and reliability as follows:

Number of Tested Units Required for Validation

A manufacturer must select a minimum number of basic models from each validation class to which the AEDM applies (validation classes are groupings of products based on equipment classes used for AEDM validation). The Department proposes the validation classes listed in Table III.5 be applicable to compressors. To validate an AEDM, the specified number of basic models from each validation class must be tested in accordance with the DOE test procedure and sampling plan in effect at the time those basic models used for validation are distributed in commerce. Testing may be conducted at a manufacturer's testing facility or a third-party testing facility. The resulting rating is directly compared to the result from the AEDM to determine the AEDM's validity. A manufacturer may develop multiple AEDMs per validation class, and each AEDM may span multiple validation classes; however, the minimum number of basic models must be validated per validation class for every AEDM a manufacturer chooses to develop. An AEDM may be applied to any basic model within the applicable validation classes at the manufacturer's discretion. All documentation of testing, the AEDM results, and subsequent comparisons to the AEDM would be required to be maintained as part of both the test data underlying the certified rating and the AEDM validation package pursuant to 10 CFR 429.71.

Table III.5 Proposed AEDM Validation Classes for Compressors

Validation Class	Minimum Number of Distinct Basic Models that Must be Tested
Rotary, Fixed-speed	2 Basic Models
Rotary, Variable-speed	2 Basic Models
Reciprocating, Fixed-speed	2 Basic Models
Reciprocating, Variable-speed	2 Basic Models

Tolerances for Validation

DOE proposes that the AEDM-predicted result for a basic model must be (for energy consumption metrics) equal to or greater than 95 percent or (for energy efficiency metrics) less than or equal to 105 percent of the tested results for that same model. Additionally, the predicted energy efficiency for each basic model calculated by applying the AEDM must meet or exceed the applicable federal energy conservation standard DOE adopts for compressors.

d. Records Retention Requirements

Consistent with provisions for other commercial and industrial equipment, DOE also proposes requirements regarding retention of certain information related to validation and use of an AEDM to certify equipment. Specifically, any manufacturer using an AEDM to generate representative values must provide to DOE upon request records showing (1) the AEDM, itself, and any mathematical modeling, engineering or statistical analysis, or computer simulation that forms the AEDM's basis; (2) equipment information, complete test data, AEDM calculations, and the statistical comparisons from the units tested that were used to validate the AEDM pursuant to section III.G.2.b; and (3) equipment information and AEDM calculations for each basic model to which the AEDM has been applied.

e. Additional AEDM Requirements

Consistent with provisions for other commercial and industrial equipment, DOE proposes to require that, if requested by DOE, a manufacturer must perform at least one of the following activities: (1) conduct a simulation before a DOE representative to predict the performance of particular basic models of the equipment to which the AEDM was applied; (2) provide analysis of previous simulations conducted by the manufacturer; and (3) conduct certification testing of basic model(s) selected by DOE.

In addition, DOE notes that, when making representations of values other than package isentropic efficiency based on the output of an AEDM, all other representations regarding package specific power, full-load actual volume flow rate, full-load operating pressure, and pressure ratio would be required to be based on the same AEDM results used to generate the represented value of package isentropic efficiency.

DOE requests feedback regarding all aspects of its proposal to permit use of an AEDM for compressors, and any data or information comparing modeled performance with the results of physical testing.

3. Enforcement Provisions

Enforcement provisions govern the process DOE would follow when performing its own assessment of basic model compliance with standards, as described under 10 CFR 429.110. In this NOPR, DOE is proposing to adopt similar requirements to those applied to other industrial equipment, specifically pumps. In the pumps test procedure final rule, DOE adopted provisions stating that DOE would assess compliance of any basic models undergoing enforcement testing based on the arithmetic mean of up to four units. 81 FR 4086 (Jan. 25, 2016). Therefore, for compressors, DOE proposes to use, when determining performance for a specific basic model, the arithmetic mean of a sample not to exceed four units.

In addition, when determining compliance for enforcement purposes, DOE proposes to adopt provisions that specify how DOE would determine the full-load operating pressure for the purposes of measuring the full-load actual volume flow rate, isentropic efficiency, specific power, and pressure ratio for any tested equipment. In addition, DOE proposes a method for determining the appropriate standard level for any tested equipment based on the tested full-load actual volume flow rate. Specifically, to verify the full-load operating pressure certified by the manufacturer, DOE proposes to perform the same procedure being proposed (see section III.D.2.i) for determining the maximum full-flow operating pressure of each unit tested, except that DOE would begin searching for maximum full-flow operating pressure at the manufacturer's certified value of full-load operating pressure prior to increasing discharge pressure. As DOE has proposed to allow manufacturers to self-declare a full-load operating pressure value of between 90 and 100 percent (inclusive) of the measured maximum full-flow operating pressure, DOE proposes to compare the measured value(s) of maximum full-flow operating pressure from a sample of one or more units to the certified value of full-load operating pressure. If a sample of more than one units is used, DOE proposes to calculate the mean of the measurements. If the certified value of full-load operating pressure is greater than or equal to 90 and less than or equal to 100 percent of the maximum full-flow operating pressure determined through DOE's testing (i.e., within the tolerance allowed by DOE in the test procedure), then DOE would use the certified value of full-load operating pressure certified by the manufacturer as the basis for determining full-load actual volume flow rate, isentropic efficiency, and other applicable values. Otherwise, DOE would use the maximum full flow operating pressure as the basis for determining the full-load actual volume flow rate, isentropic efficiency, and other applicable values. That is, if the certified value of full-load operating pressure is found to be valid, DOE will set the compressor under test to that operating pressure to determine the full-load actual volume flow rate, isentropic efficiency, specific power, and pressure ratio in accordance with the DOE test procedure. If the certified full-load operating pressure is found to be invalid, DOE will use the measured maximum full-flow operating pressure resulting from DOE's testing as the basis for determining the full-load actual volume flow rate, isentropic efficiency, specific power, and pressure ratio for any tested equipment.

Similarly, DOE proposes a procedure to verify the full-load actual volume flow rate of any certified equipment and determine the applicable full-load actual volume flow rate DOE will use when determining the standard level for any tested equipment. Specifically, DOE proposes to use the full-load actual volume flow rate determined based on verification of full-load operating pressure and compare such value to the certified value of full-load actual volume flow rate certified by the manufacturer. If DOE found the full-load operating pressure to be valid, DOE will use the full-load actual volume flow rate determined at the full-load operating pressure certified by the manufacturer. If the full-load operating pressure was found to be invalid, DOE will use the actual volume flow rate measured at the maximum full flow operating pressure as the full-load actual volume flow rate. DOE would compare the measured full-load actual volume flow rate (determined at the applicable operating pressure) from an appropriately sized sample to the certified value of full-load actual volume flow rate. If the full-load actual volume flow rate measured be DOE is within the allowances of the certified full-load actual volume flow rate specified in Table III.6, then DOE would use the manufacturer-certified value of full-load actual volume flow rate as the basis for determining the standard level for tested equipment. Otherwise, DOE would use the measured actual volume flow rate resulting from DOE's testing when determining the standard level for tested equipment. DOE believes such an approach would result in more reproducible and equitable rating of equipment and compliance determinations among DOE, manufacturers, and test labs.

Table III.6 Enforcement Allowances for Full-Load Actual Volume Flow Rate

Manufacturer Certified Full-Load Actual Volume Flow Rate (m^3/s) × 10^{-3}	Allowable Percent of the Certified Full-Load Actual Volume Flow Rate (%)
0 < and ≤ 8.3	±7
8.3 < and ≤ 25	±6
25 < and ≤ 250	±5
> 250	±4

DOE requests comment on its proposal to conduct enforcement proceedings using performance calculated as the arithmetic mean of a tested sample, not to exceed four units. In addition, DOE requests comment on its proposed provisions that specify how DOE would determine the full-load operating pressure for determination of the full-load actual volume flow rate, isentropic efficiency, specific power, pressure ratio, and the appropriate standard level (if applicable) for any tested equipment.

IV. Procedural Issues and Regulatory Review

A. Review under Executive Order 12866

The Office of Management and Budget (OMB) has determined that test procedure rulemakings do not constitute "significant regulatory actions" under section 3(f) of Executive Order 12866, Regulatory Planning and Review, 58 FR 51735 (Oct. 4, 1993). Accordingly, this action was not subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) in the Office of Management and Budget.

B. Review under the Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601 et seq.) requires preparation of an initial regulatory flexibility analysis (IFRA) for any rule that by law must be proposed for public comment, unless the agency certifies that the rule, if promulgated, would not have a significant economic impact on a substantial number of small entities. As required by Executive Order 13272, "Proper Consideration of Small Entities in Agency Rulemaking," 67 FR 53461 (Aug. 16, 2002), DOE published procedures and policies on February 19, 2003, to ensure that the potential impacts of its rules on small entities are properly considered during the DOE rulemaking process. 68 FR 7990 (Feb. 19, 2003). DOE has made its procedures and policies available on the Office of the General Counsel's website: http://energy.gov/gc/office-general-counsel.

DOE reviewed this proposed rule, which would establish new test procedures for compressors, under the provisions of the Regulatory Flexibility Act and the procedures and policies published on February 19, 2003. DOE tentatively concludes that the proposed rule, if adopted, would not result in a significant impact on a substantial number of small entities. DOE notes that certification of compressors models is not currently required because energy conservation standards do not currently exist for compressors. That is, any burden associated with testing compressors in accordance with the requirements of this test procedure would not be required until the promulgation of any energy conservation standards for compressors. On this basis, DOE maintains that the proposed test procedure has no incremental burden associated with it and a final regulatory flexibility analysis is not required. The factual basis is set forth below.

1. Small Business Determination

For the compressors manufacturing industry, the Small Business Administration (SBA) has set a size threshold, which defines those entities classified as small businesses for the purpose of the statute. DOE used the SBA's size standards to determine whether any small entities would be required to comply with the rule. The size standards are codified at 13 CFR part 121. The standards are listed by North American Industry Classification System (NAICS) code and industry description and are available at http://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf. Compressor manufacturers are classified under NAICS 333912, "Air and Gas Compressor Manufacturing." The SBA sets a threshold of 500 employees or less for an entity to be considered as a small business for this category.

a. Methodology for Estimating the Number of Small Entities

To estimate the number of small business manufacturers of equipment applicable to by this rulemaking, DOE conducted a market survey using available public information. DOE's research involved industry trade association membership directories (including CAGI), individual company and online retailer websites, and market research tools (e.g., Hoovers reports) to create a list of companies that manufacture products applicable to this rulemaking. DOE presented its list to manufacturers in MIA interviews and asked industry representatives if they were aware of any other small manufacturers during manufacturer interviews and at DOE public meetings. DOE reviewed publicly-available data and contacted select companies on its list, as necessary, to determine whether they met the SBA's definition of a small business manufacturer. DOE screened out companies that do not offer products applicable to this rulemaking, do not meet the definition of a small business, or are foreign-owned and operated.

b. Air Compressor Industry Structure and Nature of Competition

DOE identified a total of 37 manufacturers of applicable air compressor products sold in the United States. Seventeen of these manufacturers met the 500-employee threshold defined by the SBA to qualify as a small business, but only 13 were domestic companies. All 13 domestic small businesses manufacture reciprocating air compressors, while only five of the 13 manufacture rotary air compressors.

Within the air compressor industry, manufacturers can be classified into two categories; original equipment manufacturers (OEMs) and compressor packagers. OEMs manufacturer their own air-ends and assemble them with other components to create complete package air compressors. Packagers assemble motors and other accessories with air-ends purchased from other companies, resulting in a complete air compressor.

Within the rotary air compressor industry, DOE identified 20 manufacturers; 15 are OEMs and five are packagers of compressors. Of the 20 total manufacturers, seven large OEMs supply approximately 80 percent of shipments and revenues. Of the five domestic small rotary air compressor businesses identified, DOE's research indicates that two are OEMs and three are packagers.

The reciprocating air compressor market has a significantly different structure than the rotary market. The reciprocating market is highly fragmented, consisting of approximately 16 large and 17 small OEMs and packagers. Five of the 16 large businesses are members of CAGI. Eight of the 16 large manufacturers are believed to be packagers. Of the 18 identified small businesses, 13 are domestic. DOE notes that some interviewed manufacturers stated that there are potentially a large number of domestic small reciprocating air compressor manufacturers who assemble compressor packages from nearly complete components. These unidentified small manufacturers are not members of CAGI and typically have a limited marketing presence. DOE was not able to identify these small businesses. Based on this information, it is possible that DOE's list of 13 small domestic players may not include all small U.S. manufacturers in the industry. Of the 13 identified domestic reciprocating air compressor manufacturers, three are believed to be OEMs and 10 are believed to be packagers.

Table IV.1 presents both the total number of domestic small businesses offering products in each equipment class grouping as well as the breakdown between domestic small business OEMs and domestic small business packagers.

Table IV.1 Number of Domestic Small Businesses Manufacturing Air Compressors by Equipment Class Grouping

Equipment Class Grouping	Number of Domestic Small Original Equipment Manufacturers	Number of Domestic Small Packagers	Total Number of Domestic Small Businesses
Rotary Air Compressors	2	3	5
Reciprocating Air Compressors	3	10	13
Total	3	10	13*

* "Total" may not equal the sum of the other rows because one manufacturer may participate in both markets but does not get counted twice.

2. Burden of Conducting the Proposed DOE Compressor Test Procedure

Compressors would be newly regulated equipment – accordingly, DOE currently has no test procedures or standards for this equipment. As such, compressors within the scope of DOE's proposal would be required to be tested, and this may result in an accompanying burden on the manufacturers of those compressors. As discussed in the proposed sampling provisions in section III.F, this test procedure would require manufacturers to either test at least two units of each compressor model, or use an AEDM to develop a certified rating.

DOE notes that certification of compressors models is not currently required because energy conservation standards do not currently exist for compressors. That is, any burden associated with testing compressors in accordance with the requirements of this test procedure would not be required until the promulgation of any energy conservation standards for compressors. On this basis, DOE maintains that the proposed test procedure has no incremental burden associated with it and a final regulatory flexibility analysis is not required.

DOE also notes that EPCA requires manufacturers of covered equipment to use the DOE test procedure, if applicable, to make representations regarding energy efficiency or energy use of their equipment. As such, DOE is also estimating the burden of testing to determine the potential burden to manufacturers of updating associated literature or marketing materials. However, DOE notes that making representations in marketing literature regarding the energy efficiency or energy use of applicable compressor models is voluntary. As such, manufacturers that do not currently make representations of energy efficiency or energy use may continue to elect not to do so; thus incurring no additional burden.

During its market survey, DOE performed research and requested information regarding the energy efficiency or energy use representations currently being made by manufacturers of compressors. DOE found that for rotary compressors, the majority of those making any representation of energy efficiency or energy use were manufacturers already participating in CAGI's voluntary Performance Verification Program. Of the small businesses identified by DOE, only one manufacturer currently participates in this program.

Both the CAGI Performance Verification Program and the test procedure proposed in this NOPR are based on the same industry test procedure, ISO 1217:2009. DOE believes the modifications to ISO 1217:2009 (as described in section III.D.2 of this document) do not represent significant changes and would not result in any incremental burden for those manufacturers already performing testing as part of CAGI's program. Consequently, DOE believes that manufacturers participating in the CAGI Performance Verification Program would not incur any incremental burden associated with conducting DOE's proposed test procedure.

For manufacturers of rotary compressor equipment that make representations of compressor energy use or energy efficiency but are not currently participating in CAGI's program, DOE's research indicates such manufacturers typically test to ISO 1217:2009 using internal test facilities, rather than utilizing a third-party laboratory, as specified by the CAGI program. As such, DOE believes that the proposed use of ISO 1217:2009, including any modifications, would not result in any incremental burden for manufacturers of rotary compressors that do not participate in CAGI's program.

However, DOE notes that CAGI's voluntary performance verification program does not include provisions for the testing and certification of reciprocating compressors. Furthermore, DOE's research indicates that manufacturers of reciprocating compressors do not typically make representations of the energy efficiency or energy use of their equipment.

Based on its research and discussions presented in this section, DOE believes that the proposed test procedure does not represent a significant incremental burden for any of the identified small entities, and the preparation of a final regulatory flexibility analysis is not required. DOE would transmit the certification and supporting statement of factual basis to the Chief Counsel for Advocacy of the Small Business Administration for review under 5 U.S.C. 605(b).

However, DOE notes that it has prepared a full assessment of testing and compliance cost, as they related to potential energy conservation standards, in DOE’s concurrent compressors energy conservation standard rulemaking (Docket No. EERE-2013-BT-STD-0040). In that rulemaking, DOE assesses costs to both small domestic manufacturers and the industry as a whole.

DOE requests comment on its conclusion that the proposed rule does not have a significant impact on a substantial number of small entities.

C. Review under the Paperwork Reduction Act of 1995

All collections of information from the public by a Federal agency must receive prior approval from OMB. DOE has established regulations for the certification and recordkeeping requirements for covered consumer products and industrial equipment. 10 CFR Part 429, Subpart B. DOE published a notice of public meeting and availability of the Framework Document considering energy conservation standards for compressors on February 5, 2014. 79 FR 6839 (Feb. 5, 2014). In an application to renew the OMB information collection approval for DOE's certification and recordkeeping requirements, DOE included an estimated burden for manufacturers of compressors in case DOE ultimately sets energy conservation standards for this equipment. OMB has approved the revised information collection for DOE's certification and recordkeeping requirements. 80 FR 5099 (January 30, 2015). DOE estimated that it would take each respondent approximately 30 hours total per company per year to comply with the certification and recordkeeping requirements based on 20 hours of technician/technical work and 10 hours clerical work to submit the Compliance and Certification Management System templates. This rulemaking would include recordkeeping requirements on manufacturers that are associated with executing and maintaining the test data for this equipment. DOE notes that the certification requirements would be established in a final rule establishing energy conservation standards for compressors. DOE recognizes that recordkeeping burden may vary substantially based on company preferences and practices.

DOE requests comment on the burden estimate to comply with the proposed recordkeeping requirements.

Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to comply with, a collection of information subject to the requirements of the PRA, unless that collection of information displays a currently valid OMB control number.

D. Review under the National Environmental Policy Act of 1969

In this proposed rule, DOE proposes test procedure amendments that it expects will be used to develop and implement future energy conservation standards for compressors. DOE has determined that this rule falls into a class of actions that are categorically excluded from review under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) and DOE's implementing regulations at 10 CFR part 1021. Specifically, this proposed rule would create a new test procedure without affecting the amount, quality or distribution of energy usage, and, therefore, would not result in any environmental impacts. Thus, this rulemaking is covered by Categorical Exclusion A6 under 10 CFR part 1021, subpart D, which applies to any rulemaking that creates a new rule without changing the environmental effect of that rule. Accordingly, neither an environmental assessment nor an environmental impact statement is required.

E. Review under Executive Order 13132

Executive Order 13132, "Federalism," 64 FR 43255 (August 4, 1999) imposes certain requirements on agencies formulating and implementing policies or regulations that preempt State law or that have Federalism implications. The Executive Order requires agencies to examine the constitutional and statutory authority supporting any action that would limit the policymaking discretion of the States and to carefully assess the necessity for such actions. The Executive Order also requires agencies to have an accountable process to ensure meaningful and timely input by State and local officials in the development of regulatory policies that have Federalism implications. On March 14, 2000, DOE published a statement of policy describing the intergovernmental consultation process it would follow in the development of such regulations. 65 FR 13735 (Mar. 14, 2000). DOE has examined this proposed rule and has determined that it would not have a substantial direct effect on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. EPCA governs and prescribes Federal preemption of State regulations as to energy conservation for the products and equipment that are the subject of this proposed rule. States can petition DOE for exemption from such preemption to the extent, and based on criteria, set forth in EPCA. (42 U.S.C. 6297(d)) No further action is required by Executive Order 13132.

F. Review under Executive Order 12988

Regarding the review of existing regulations and the promulgation of new regulations, section 3(a) of Executive Order 12988, "Civil Justice Reform," 61 FR 4729 (Feb. 7, 1996), imposes on Federal agencies the general duty to adhere to the following requirements: (1) eliminate drafting errors and ambiguity; (2) write regulations to minimize litigation; (3) provide a clear legal standard for affected conduct rather than a general standard; and (4) promote simplification and burden reduction. Section 3(b) of Executive Order 12988 specifically requires that Executive agencies make every reasonable effort to ensure that the regulation: (1) clearly specifies the preemptive effect, if any; (2) clearly specifies any effect on existing Federal law or regulation; (3) provides a clear legal standard for affected conduct while promoting simplification and burden reduction; (4) specifies the retroactive effect, if any; (5) adequately defines key terms; and (6) addresses other important issues affecting clarity and general draftsmanship under any guidelines issued by the Attorney General. Section 3(c) of Executive Order 12988 requires Executive agencies to review regulations in light of applicable standards in sections 3(a) and 3(b) to determine whether they are met or it is unreasonable to meet one or more of them. DOE has completed the required review and determined that, to the extent permitted by law, the proposed rule meets the relevant standards of Executive Order 12988.

G. Review under the Unfunded Mandates Reform Act of 1995

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA) requires each Federal agency to assess the effects of Federal regulatory actions on State, local, and Tribal governments and the private sector. Pub. L. No. 104-4, sec. 201 (codified at 2 U.S.C. 1531). For a proposed regulatory action likely to result in a rule that may cause the expenditure by State, local, and Tribal governments, in the aggregate, or by the private sector of $100 million or more in any one year (adjusted annually for inflation), section 202 of UMRA requires a Federal agency to publish a written statement that estimates the resulting costs, benefits, and other effects on the national economy. (2 U.S.C. 1532(a), (b)) The UMRA also requires a Federal agency to develop an effective process to permit timely input by elected officers of State, local, and Tribal governments on a proposed "significant intergovernmental mandate," and requires an agency plan for giving notice and opportunity for timely input to potentially affected small governments before establishing any requirements that might significantly or uniquely affect small governments. On March 18, 1997, DOE published a statement of policy on its process for intergovernmental consultation under UMRA. 62 FR 12820 (Mar. 18, 1997); also available at http://energy.gov/gc/office-general-counsel. DOE examined this proposed rule according to UMRA and its statement of policy and determined that the rule contains neither an intergovernmental mandate, nor a mandate that may result in the expenditure of $100 million or more in any year, so these requirements do not apply.

H. Review under the Treasury and General Government Appropriations Act, 1999

Section 654 of the Treasury and General Government Appropriations Act, 1999 (Pub. L. 105-277) requires Federal agencies to issue a Family Policymaking Assessment for any rule that may affect family well-being. This rule would not have any impact on the autonomy or integrity of the family as an institution. Accordingly, DOE has concluded that it is not necessary to prepare a Family Policymaking Assessment.

I. Review under Executive Order 12630

DOE has determined, under Executive Order 12630, "Governmental Actions and Interference with Constitutionally Protected Property Rights" 53 FR 8859 (March 18, 1988), that this regulation would not result in any takings that might require compensation under the Fifth Amendment to the U.S. Constitution.

J. Review under Treasury and General Government Appropriations Act, 2001

Section 515 of the Treasury and General Government Appropriations Act, 2001 (44 U.S.C. 3516 note) provides for agencies to review most disseminations of information to the public under guidelines established by each agency pursuant to general guidelines issued by OMB. OMB's guidelines were published at 67 FR 8452 (February 22, 2002), and DOE's guidelines were published at 67 FR 62446 (October 7, 2002). DOE has reviewed this proposed rule under the OMB and DOE guidelines and has concluded that it is consistent with applicable policies in those guidelines.

K. Review under Executive Order 13211

Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use," 66 FR 28355 (May 22, 2001), requires Federal agencies to prepare and submit to OMB, a Statement of Energy Effects for any proposed significant energy action. A "significant energy action" is defined as any action by an agency that promulgated or is expected to lead to promulgation of a final rule, and that: (1) is a significant regulatory action under Executive Order 12866, or any successor order; and (2) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (3) is designated by the Administrator of OIRA as a significant energy action. For any proposed significant energy action, the agency must give a detailed statement of any adverse effects on energy supply, distribution, or use should the proposal be implemented, and of reasonable alternatives to the action and their expected benefits on energy supply, distribution, and use.

The proposed regulatory action to amend the test procedure for measuring the energy efficiency of compressors is not a significant regulatory action under Executive Order 12866. Moreover, it would not have a significant adverse effect on the supply, distribution, or use of energy, nor has it been designated as a significant energy action by the Administrator of OIRA. Therefore, it is not a significant energy action, and, accordingly, DOE has not prepared a Statement of Energy Effects.

L. Review under Section 32 of the Federal Energy Administration Act of 1974

Under section 301 of the Department of Energy Organization Act (Pub. L. 95–91; 42 U.S.C. 7101), DOE must comply with section 32 of the Federal Energy

Administration Act of 1974, as amended by the Federal Energy Administration Authorization Act of 1977. (15 U.S.C. 788; FEAA) Section 32 essentially provides in relevant part that, where a proposed rule authorizes or requires use of commercial standards, the notice of proposed rulemaking must inform the public of the use and background of such standards. In addition, section 32(c) requires DOE to consult with the Attorney General and the Chairman of the Federal Trade Commission (FTC) concerning the impact of the commercial or industry standards on competition.

The proposed rule incorporates testing methods contained in ISO Standard 1217:2009, "Displacement compressors – Acceptance tests," sections 2, 3, and 4; subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), 6.2(h); and subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C.

The DOE has evaluated the ISO 1217:2009 standard and is unable to conclude whether they fully comply with the requirements of section 32(b) of the FEAA, (i.e., that they were developed in a manner that fully provides for public participation, comment, and review). DOE would consult with the Attorney General and the Chairman of the FTC concerning the impact of these test procedures on competition, prior to prescribing a final rule.

M. Description of Materials Incorporated by Reference

In this test procedure NOPR, DOE proposes to incorporate by reference the testing methods contained in certain applicable sections of ISO Standard 1217:2009, "Displacement compressors – Acceptance tests," sections 2, 3, and 4; subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), and 6.2(h); and subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C.

Members of the compressors industry developed ISO 1217:2009, which contains methods for determining inlet and discharge pressures, actual volume flow rate, and packaged compressor power input for electrically driven packaged displacement compressors.

Copies of ISO 1217 can be obtained from the International Organization for Standardization at Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, +41 22 749 01 11, or by going to www.iso.org.

V. Public Participation

A. Attendance at Public Meeting

The time, date and location of the public meeting are listed in the DATES and ADDRESSES sections at the beginning of this document. If you plan to attend the public meeting, please notify Ms. Brenda Edwards at (202) 586-2945 or Brenda.Edwards@ee.doe.gov.

Please note that foreign nationals visiting DOE Headquarters are subject to advance security screening procedures which require advance notice prior to attendance at the public meeting. If a foreign national wishes to participate in the public meeting, please inform DOE of this fact as soon as possible by contacting Ms. Regina Washington at (202) 586–1214 or by e-mail: Regina.Washington@ee.doe.gov so that the necessary procedures can be completed.

DOE requires visitors to have laptops and other devices, such as tablets, checked upon entry into the building. Any person wishing to bring these devices into the Forrestal Building will be required to obtain a property pass. Visitors should avoid bringing these devices, or allow an extra 45 minutes to check in. Please report to the visitor's desk to have devices checked before proceeding through security.

Due to the REAL ID Act implemented by the Department of Homeland Security (DHS), there have been recent changes regarding ID requirements for individuals wishing to enter Federal buildings from specific states and U.S. territories. Driver's licenses from the following states or territory will not be accepted for building entry and one of the alternate forms of ID listed below will be required. DHS has determined that regular driver's licenses (and ID cards) from the following jurisdictions are not acceptable for entry into DOE facilities: Alaska, American Samoa, Arizona, Louisiana, Maine, Massachusetts, Minnesota, New York, Oklahoma, and Washington. Acceptable alternate forms of Photo-ID include: U.S. Passport or Passport Card; an Enhanced Driver's License or Enhanced ID-Card issued by the states of Minnesota, New York or Washington (Enhanced licenses issued by these states are clearly marked Enhanced or Enhanced Driver's License); a military ID or other Federal government issued Photo-ID card.

In addition, you can attend the public meeting via webinar. Webinar registration information, participant instructions, and information about the capabilities available to webinar participants will be published on DOE's website: https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/58. Participants are responsible for ensuring their systems are compatible with the webinar software.

B. Procedure for Submitting Prepared General Statements for Distribution

Any person who has plans to present a prepared general statement may request that copies of his or her statement be made available at the public meeting. Such persons may submit requests, along with an advance electronic copy of their statement in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format, to the appropriate address shown in the ADDRESSES section at the beginning of this document. The request and advance copy of statements must be received at least one week before the public meeting and may be emailed, hand-delivered, or sent by mail. DOE prefers to receive requests and advance copies via email. Please include a telephone number to enable DOE staff to make a follow-up contact, if needed.

C. Conduct of Public Meeting

DOE will designate a DOE official to preside at the public meeting and may also use a professional facilitator to aid discussion. The meeting will not be a judicial or evidentiary-type public hearing, but DOE will conduct it in accordance with section 336 of EPCA (42 U.S.C. 6306). A court reporter will be present to record the proceedings and prepare a transcript. DOE reserves the right to schedule the order of presentations and to establish the procedures governing the conduct of the public meeting. After the public meeting and until the end of the comment period, interested parties may submit further comments on the proceedings and any aspect of the rulemaking.

The public meeting will be conducted in an informal, conference style. DOE will present summaries of comments received before the public meeting, allow time for prepared general statements by participants, and encourage all interested parties to share their views on issues affecting this rulemaking. Each participant will be allowed to make a general statement (within time limits determined by DOE), before the discussion of specific topics. DOE will permit, as time permits, other participants to comment briefly on any general statements.

At the end of all prepared statements on a topic, DOE will permit participants to clarify their statements briefly and comment on statements made by others. Participants should be prepared to answer questions by DOE and by other participants concerning these issues. DOE representatives may also ask questions of participants concerning other matters relevant to this rulemaking. The official conducting the public meeting will accept additional comments or questions from those attending, as time permits. The presiding official will announce any further procedural rules or modification of the above procedures that may be needed for the proper conduct of the public meeting.

A transcript of the public meeting will be included in the docket, which can be viewed as described in the Docket section at the beginning of this notice. In addition, any person may buy a copy of the transcript from the transcribing reporter.

D. Submission of Comments

DOE will accept comments, data, and information regarding this proposed rule before or after the public meeting, but no later than the date provided in the DATES section at the beginning of this proposed rule. Interested parties may submit comments using any of the methods described in the ADDRESSES section at the beginning of this document.

Submitting comments via regulations.gov. The regulations.gov web page will require you to provide your name and contact information. Your contact information will be viewable to DOE Building Technologies staff only. Your contact information will not be publicly viewable except for your first and last names, organization name (if any), and submitter representative name (if any). If your comment is not processed properly because of technical difficulties, DOE will use this information to contact you. If DOE cannot read your comment due to technical difficulties and cannot contact you for clarification, DOE may not be able to consider your comment.

However, your contact information will be publicly viewable if you include it in the comment or in any documents attached to your comment. Any information that you do not want to be publicly viewable should not be included in your comment, nor in any document attached to your comment. Persons viewing comments will see only first and last names, organization names, correspondence containing comments, and any documents submitted with the comments.

Do not submit to regulations.gov information for which disclosure is restricted by statute, such as trade secrets and commercial or financial information (hereinafter referred to as Confidential Business Information (CBI)). Comments submitted through regulations.gov cannot be claimed as CBI. Comments received through the website will waive any CBI claims for the information submitted. For information on submitting CBI, see the Confidential Business Information section.

DOE processes submissions made through regulations.gov before posting. Normally, comments will be posted within a few days of being submitted. However, if large volumes of comments are being processed simultaneously, your comment may not be viewable for up to several weeks. Please keep the comment tracking number that regulations.gov provides after you have successfully uploaded your comment.

Submitting comments via email, hand delivery, or mail. Comments and documents submitted via email, hand delivery, or mail also will be posted to regulations.gov. If you do not want your personal contact information to be publicly viewable, do not include it in your comment or any accompanying documents. Instead, provide your contact information on a cover letter. Include your first and last names, email address, telephone number, and optional mailing address. The cover letter will not be publicly viewable as long as it does not include any comments.

Include contact information each time you submit comments, data, documents, and other information to DOE. If you submit via mail or hand delivery, please provide all items on a CD, if feasible. It is not necessary to submit printed copies. No facsimiles (faxes) will be accepted.

Comments, data, and other information submitted to DOE electronically should be provided in PDF (preferred), Microsoft Word or Excel, WordPerfect, or text (ASCII) file format. Provide documents that are not secured, written in English and free of any defects or viruses. Documents should not contain special characters or any form of encryption and, if possible, they should carry the electronic signature of the author.

Campaign form letters. Please submit campaign form letters by the originating organization in batches of between 50 to 500 form letters per PDF or as one form letter with a list of supporters' names compiled into one or more PDFs. This reduces comment processing and posting time.

Confidential Business Information. According to 10 CFR 1004.11, any person submitting information that he or she believes to be confidential and exempt by law from public disclosure should submit via email, postal mail, or hand delivery two well-marked copies: one copy of the document marked confidential including all the information believed to be confidential, and one copy of the document marked non-confidential with the information believed to be confidential deleted. Submit these documents via email or on a CD, if feasible. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

Factors of interest to DOE when evaluating requests to treat submitted information as confidential include: (1) A description of the items; (2) whether and why such items are customarily treated as confidential within the industry; (3) whether the information is generally known by or available from other sources; (4) whether the information has previously been made available to others without obligation concerning its confidentiality; (5) an explanation of the competitive injury to the submitting person which would result from public disclosure; (6) when such information might lose its confidential character due to the passage of time; and (7) why disclosure of the information would be contrary to the public interest. See 10 CFR 429.7.

It is DOE's policy that all comments be included in the public docket, without change and as received, including any personal information provided in the comments (except information deemed to be exempt from public disclosure).

E. Issues about Which DOE Seeks Comment

Although DOE welcomes comments on any aspect of this proposal, DOE is particularly interested in receiving comments and views of interested parties concerning the following issues:

1. DOE requests comment on the proposed definitions for compressor and pressure ratio, as well as the definitions referenced in ISO 1217:2009.

2. DOE requests comment on the proposed lower limit of pressure ratio for compressors of "greater than 1.3."

3. DOE requests comment on its proposed definition of air compressor and its use in limiting the scope of applicability of this test procedure.

4. DOE requests comment on the proposed definitions for bare compressor, driver, and mechanical equipment.

5. DOE requests comment on the proposed definition of ancillary equipment, and whether a comprehensive list of potential ancillary equipment is more appropriate. If a comprehensive list of potential ancillary equipment is preferred, DOE requests information on what equipment should be on that list.

6. DOE requests comment on its position that all ancillary equipment distributed in commerce with an air compressor be installed when testing to evaluate the energy performance of the air compressor. DOE requests comment on a potential alternative approach, in which DOE could generate a list of specific ancillary equipment that must be installed to ensure that the test result is representative of compressor performance; equipment on this list would not be optional, regardless of how that compressor model is distributed in commerce. If the alternative approach is preferred, DOE requests comments on what ancillary equipment be required to be installed to representatively measure compressor energy performance and how to evaluate compressor performance if an air compressor is distributed in commerce without certain items on the list.

7. DOE requests comment on its proposed definitions of rotary compressor, reciprocating compressor, and positive displacement compressor and their use in defining the scope of applicability of this test procedure.

8. DOE requests comment on its proposal to establish test procedures for only brushless electric motor-driven equipment and on its proposed definition of brushless electric motor.

9. DOE requests comment on its proposed definition of compressor motor nominal horsepower. Additionally, DOE seeks comment on whether motors not covered in subpart B and subpart X of part 431 ("uncovered motors") are incorporated into air compressors within the scope of this proposed test procedure. If so, DOE requests comment on how prevalent these uncovered motors are, and whether the test methods described in subpart B and subpart X of part 431 would be applicable to determine the compressor motor nominal horsepower of these uncovered motors. If the test methods described in subpart B and subpart X of 10 CFR part 431 are not applicable to uncovered motors, DOE requests comment on what test methods could be used to determine their compressor motor nominal horsepower.

10. DOE requests comment on the proposal to include only compressors with a compressor motor nominal horsepower of greater than or equal to 1 and less than or equal to 500 within the scope of this test procedure.

11. DOE requests comment on its characterization of the rotary compressor market by pressure ranges, and whether the reciprocating compressor market is similarly characterized.

12. DOE requests comment on the proposed definitions of full-load operating pressure, maximum full-flow operating pressure, and full-load actual volume flow rate, and actual volume flow rate.

13. DOE requests comment on the proposal to include only compressors with a full-load operating pressure greater than or equal to 31 psig and less than or equal to 225 psig within the scope of this test procedure.

14. DOE requests comment on the proposed load points and weighting factors for package isentropic efficiency for both fixed-speed and variable-speed compressors.

15. DOE requests comment on its proposed definition for full-load package isentropic efficiency, and its use as the metric for fixed-speed compressors.

16. DOE requests comment on its proposed definition for part-load package isentropic efficiency, and its use as the metric for variable-speed compressors.

17. DOE requests comment on its proposal to incorporate by reference certain applicable sections of ISO 1217: 2009 as the basis of the DOE test procedure for compressors. DOE

requests comment on the proposal not to incorporate by reference specific sections and annexes as explained in this section.

18. DOE requests comment regarding the proposed ambient conditions required for testing, and if they are sufficient to produce repeatable and reproducible test results.

19. DOE requests comment on the proposed voltage, frequency, voltage unbalance, and total harmonic distortion requirements when performing a compressor test. Specifically, DOE requests comments on whether these tolerances can be achieved in typical compressor test labs, or whether specialized power supplies or power conditioning equipment would be required.

20. DOE requests comment on the proposed equipment configuration: that the inlet of the air compressor under test be open to the atmosphere and take in ambient air, and whether all air compressors can be configured and tested in this manner.

21. DOE requests comment on the proposed requirements for equipment configuration.

22. DOE requests comment regarding the proposed packaged compressor power input measurement equipment requirements.

23. DOE requests comment to help clarify these ambiguities contained in section 5.2.1 of ISO 1217:2009. Specifically, DOE requests potential quantitative explanations and instructions related to the following items: pressure tap installation locations; methods to

verify "leak-free" pipe connections; "short as possible" and of "sufficient diameter"; testing "tightness"; mounting instruments so that the unit is "not susceptible to disturbing vibrations"; how and where to test for "pressure waves" and how the piping installation can be "corrected;" how to calibrate transmitters and gauges under "pressure and temperature conditions similar to those prevailing during the test"; how to correct dead-weight gauges for "gravitational acceleration at the location of the instrument"; where to install "a receiver with inlet throttling" to correct for flow pulsations; and how a restricting orifice may be used to reduce oscillation of gauges. Finally, DOE requests comment on its proposals regarding discharge piping and pressure taps.

24. DOE requests comment regarding the proposed density measurement equipment requirements.

25. DOE requests comment on the proposal to allow manufacturers to self-declare the full-load operating pressure between 90 and 100 percent of the measured maximum full-flow operating pressure, and whether a smaller or larger range should be used.

26. DOE requests comment on the proposed method for determining maximum full-flow operating pressure, full-load operating pressure, and full-load actual volume flow rate of a compressor.

27. DOE requests comment regarding whether any more specific instructions would be required to determine the maximum full-flow operating pressure for variable-speed

compressors in addition to the proposal that testing is to be conducted at maximum speed, and no speed reduction is allowed during the test.

28. DOE requests comment on its proposal regarding applicable representations of energy and non-energy metrics for compressors.

29. DOE requests comment on any additional metrics that manufacturers often use when making representations of compressor energy use or efficiency.

30. DOE requests comment on the proposed sampling plan for certification of compressor models.

31. DOE requests feedback regarding all aspects of its proposal to permit use of an AEDM for compressors, and any data or information comparing modeled performance with the results of physical testing.

32. DOE requests comment on its proposal to conduct enforcement proceedings using performance calculated as the arithmetic mean of a tested sample, not to exceed four units.

33. DOE requests comment on its proposed provisions that specify how DOE would determine the full-load operating pressure for determination of the full-load actual volume flow rate, isentropic efficiency, specific power, pressure ratio, and the appropriate standard level (if applicable) for any tested equipment.

34. DOE requests comment on its conclusion that the proposed rule does not have a significant impact on a substantial number of small entities.

35. DOE requests comment on the burden estimate to comply with the proposed recordkeeping requirements.

VI. Approval of the Office of the Secretary

The Secretary of Energy has approved publication of this proposed rule.

List of Subjects

10 CFR Part 429

Administrative practice and procedure, Confidential business information, Energy conservation, Imports, Intergovernmental relations, Small businesses.

10 CFR Part 431

Administrative practice and procedure, Confidential business information, Energy conservation, Household appliances, Imports, Incorporation by reference, Intergovernmental relations, Small businesses.

Issued in Washington, DC, on April 22, 2016.

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Kathleen B. Hogan
Deputy Assistant Secretary for Energy Efficiency
Energy Efficiency and Renewable Energy

For the reasons stated in the preamble, DOE proposes to amend parts 429 and 431 of Chapter II, subchapter D of Title 10, Code of Federal Regulations as set forth below:

PART 429 – CERTIFICATION, COMPLIANCE, AND ENFORCEMENT FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT

1. The authority citation for part 429 continues to read as follows:

Authority: 42 U.S.C. 6291–6317.

2. In §429.2 revise paragraph (a) to read as follows:

§429.2 Definitions.

(a) The definitions found in §§ 430.2, 431.2, 431.62, 431.72, 431.82, 431.92, 431.102, 431.132, 431.152, 431.192, 431.202, 431.222, 431.242, 431.262, 431.282, 431.292, 431.302, 431.322, 431.342, 431.442, and 431.462 of this chapter apply for purposes of this part.

*   *   *   *   *

3. Add §429.61 to read as follows:

§429.61 Compressors.

(a) Determination of represented value. Manufacturers must determine the represented value, which includes the certified rating, for each basic model of compressor either by testing in conjunction with the applicable sampling provisions, or by applying an AEDM.

(1) Units to be tested. (i) If the represented value is determined through testing, the general requirements of §429.11 apply; and

(ii) For each basic model selected for testing, a sample of sufficient size must be randomly selected and tested to ensure that—

(A) Any represented value of the full- or part-load package isentropic efficiency or other measure of energy efficiency of a basic model for which customers would favor higher values is less than or equal to the lower of:

(*1*) The mean of the sample, where:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

and $\bar{x}$ is the sample mean; n is the number of samples; and x_i is the measured value for the i^{th} sample;

Or,

(2) The lower 95 percent confidence limit (LCL) of the true mean divided by 0.95, where:

$$\mathrm{LCL} = \bar{x} - t_{0.95}\left(\frac{s}{\sqrt{n}}\right)$$

and $\bar{x}$ is the sample mean; s is the sample standard deviation; n is the number of samples; and $t_{0.95}$ is the t statistic for a 95 percent one-tailed confidence interval with n–1 degrees of freedom (from appendix A of subpart B);

And

(B) Package Specific Power. The representative value(s) of package specific power of a basic model must be the mean of the package specific power measurement(s) for each tested unit of the basic model.

(2) Alternative efficiency determination methods. In lieu of testing, any represented value of efficiency, consumption, or other non-energy metrics listed in paragraph (a)(3) of this section for a basic model may be determined through the application of an AEDM pursuant to the requirements of §429.70 and the provisions of this section, where:

(i) Any represented values of package isentropic efficiency or other measure of energy consumption of a basic model for which customers would favor higher values must be less than or equal to the value determined through the application of the AEDM, and

(ii) Any represented values of package specific power, pressure ratio, full-load actual volume flow rate, or full-load operating pressure must be the value determined through the application of the AEDM that corresponds to the represented value of package isentropic efficiency determined in paragraph (a)(2)(i) of this section.

(3) Representations of non-energy metrics. (i) Full-load actual volume flow rate. The representative value of full-load actual volume flow rate of a basic model must be either:

(A) The mean of the full-load actual volume flow rate for the units in the sample; or

(B) The value determined through the application of an AEDM pursuant to the requirements of §429.70.

(ii) Full-load operating pressure. The representative value of full-load operating pressure of a basic model must be greater than or equal to 90-perent of :

(A) The mean of the maximum full-flow operating pressure for the units in the sample, or

(B) The value determined through the application of an AEDM pursuant to the requirements of §429.70.

(iii) Pressure Ratio. The representative value of pressure ratio of a basic model must be either the mean of the pressure ratio for the units in the sample, or the value determined through the application of an AEDM pursuant to the requirements of §429.70.

4. Section 429.70 is amended by adding paragraph (h) to read as follows:

§429.70 Alternative methods for determining energy efficiency and energy use.

*   *   *   *   *

(h) Alternative efficiency determination method (AEDM) for compressors. (1) Criteria an AEDM must satisfy. A manufacturer may not apply an AEDM to a basic model to determine its efficiency pursuant to this section, unless:

(i) The AEDM is derived from a mathematical model that estimates the energy efficiency or energy consumption characteristics of the basic model as measured by the applicable DOE test procedure;

(ii) The AEDM is based on engineering or statistical analysis, computer simulation or modeling, or other analytic evaluation of performance data; and

(iii) The manufacturer has validated the AEDM, in accordance with paragraph (h)(2) of this section.

(2) Validation of an AEDM. Before using an AEDM, the manufacturer must validate the AEDM's accuracy and reliability as follows:

(i) The manufacturer must select at least the minimum number of basic models for each validation class specified in paragraph (h)(2)(iv) of this section to which the particular AEDM applies. Using the AEDM, calculate the energy use or energy efficiency for each of the selected basic models. Test each basic model in accordance with 10 CFR 429.61(a) and determine the represented value(s). Compare the results from the testing and the AEDM output according to paragraph (h)(2)(ii) of this section. The manufacturer is responsible for ensuring the accuracy and repeatability of the AEDM.

(ii) Individual Model Tolerances:

(A) The predicted representative values for each model calculated by applying the AEDM may not be more than five percent greater (for measures of efficiency) or less (for measures of consumption) than the values determined from the corresponding test of the model.

(B) The predicted package isentropic efficiency for each model calculated by applying the AEDM must meet or exceed the applicable federal energy conservation standard.

(iii) Additional Test Unit Requirements:

(A) Each AEDM must be supported by test data obtained from physical tests of current models; and

(B) Test results used to validate the AEDM must meet or exceed current, applicable Federal standards as specified in part 431 of this chapter;

(C) Each test must have been performed in accordance with the applicable DOE test procedure with which compliance is required at the time the basic models used for validation are distributed in commerce; and

(iv) Compressor Validation Classes

Validation Class	Minimum Number of Distinct Models that Must be Tested
Rotary, Fixed-speed	2 Basic Models
Rotary, Variable-speed	2 Basic Models
Reciprocating, Fixed-speed	2 Basic Models
Reciprocating, Variable-speed	2 Basic Models

(3) AEDM Records Retention Requirements. If a manufacturer has used an AEDM to determine representative values pursuant to this section, the manufacturer must have available upon request for inspection by the Department records showing:

(i) The AEDM, including the mathematical model, the engineering or statistical analysis, and/or computer simulation or modeling that is the basis of the AEDM;

(ii) Equipment information, complete test data, AEDM calculations, and the statistical comparisons from the units tested that were used to validate the AEDM pursuant to paragraph (h)(2) of this section; and

(iii) Equipment information and AEDM calculations for each basic model to which the AEDM has been applied.

(4) Additional AEDM Requirements. If requested by the Department, the manufacturer must:

(i) Conduct simulations before representatives of the Department to predict the performance of particular basic models of the equipment to which the AEDM was applied;

(ii) Provide analyses of previous simulations conducted by the manufacturer; and/or

(iii) Conduct certification testing of basic models selected by the Department.

5. Section 429.110 is amended by revising paragraph (e)(1)(iv) to read as follows:

§429.110 Enforcement testing.

* * * * *

(e) * * *

(1) * * *

(iv) For pumps and compressors, DOE will use an initial sample size of not more than four units and will determine compliance based on the arithmetic mean of the sample.

* * * * *

6. Section 429.134 is amended by adding paragraph (k) as follows:

§429.134 Product-specific enforcement provisions.

* * * * *

(k) Compressors—(1) Verification of full-load operating pressure. The maximum full flow operating pressure of each tested unit of the basic model will be measured pursuant to the test requirements of appendix A to subpart T of part 431, where the value of full-load operating pressure certified by the manufacturer will be the starting point of the test method prior to increasing discharge pressure. The certified rating for full-load operating pressure will be considered valid only if the certified rating for full-load operating pressure is greater than or equal to 90 percent of and less than or equal to the measured maximum full-flow operating pressure (either the measured maximum full flow operating pressure for a single unit sample or the mean of the measured maximum full flow operating pressures for a multiple unit sample).

(i) If the certified full-load operating pressure is found to be valid, then the certified value will be used as the full-load operating pressure and will be the basis for determination of full-load actual volume flow rate, pressure ratio, specific power, and isentropic efficiency.

(ii) If the rated value of full-load operating pressure is found to be invalid, then the measured maximum full-flow operating pressure will be used as the full-load operating pressure and will be the basis for determination of full-load actual volume flow rate, pressure ratio, specific power, and isentropic efficiency.

(2) Verification of full-load actual volume flow rate. The measured full-load actual volume flow rate will be measured, pursuant to the test requirements of appendix A to subpart T of part 431, at the full-load operating pressure determined in paragraph (j)(1) of this section. The certified full-load actual volume flow rate will be considered valid only if the measurement(s) (either the measured full-load actual volume flow rate for a single unit sample or the average of the measured values for a multiple unit sample) are within the percentage of the certified full-load actual volume flow rate specified in Table 1 of this paragraph:

Table 1 Allowable Percentage Deviation from the Certified Full-Load Actual Volume Flow Rate.

Manufacturer Certified Full-Load Actual Volume Flow Rate (m^3/s) × 10^{-3}	**Allowable Percent Of The Certified Full-Load Actual Volume Flow Rate (%)**
0 < and ≤ 8.3	±7
8.3 < and ≤ 25	±6
25 < and ≤ 250	±5
> 250	±4

(i) If the representative value of full-load actual volume flow rate is found to be valid, the full-load actual volume flow rate certified by the manufacturer will be used as the basis for determination of the applicable standard.

(ii) If the representative value of full-load actual volume flow rate is found to be invalid, the mean of all the measured full-load actual volume flow rate values determined from the tested unit(s) will serve as the basis for determination of the applicable standard.

PART 431 – ENERGY EFFICIENCY PROGRAM FOR CERTAIN COMMERCIAL AND INDUSTRIAL EQUIPMENT

7. The authority citation for part 431 continues to read as follows:

Authority: 42 U.S.C. 6291-6317.

8. Add subpart T to part 431 to read as follows:

SUBPART T – Compressors

Sec.

SUBPART T – Compressors

§431.341 Purpose and scope.

This subpart contains definitions, materials incorporated by reference, test procedures, and energy conservation requirements for compressors, pursuant to Part A-1 of Title III of the Energy Policy and Conservation Act, as amended, 42 U.S.C. 6311–6317.

§431.342 Definitions concerning compressors.

The following definitions are applicable to this subpart, including appendix A. In cases where there is a conflict, the language of the definitions adopted in this section take precedence over any descriptions or definitions found in any other source, including in the 2009 version of ISO Standard 1217, "Displacement compressors – Acceptance tests" (ISO 1217:2009) (incorporated by reference, see §431.343). In cases where definitions reference design intent, DOE will consider all relevant information, including marketing materials, labels and certifications, and equipment design, to determine design intent.

Actual volume flow rate means the volume flow rate of air, compressed and delivered at the standard discharge point, referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point, and as determined in accordance with the test procedures prescribed in §431.344.

Air compressor means a compressor designed to compress air that has an inlet open to the atmosphere or other source of air, and is made up of a compression element (bare compressor), driver(s), mechanical equipment to drive the compressor element, and any ancillary equipment.

Ancillary equipment means any equipment distributed in commerce with an air compressor that is not a bare compressor, driver, or mechanical equipment. Ancillary equipment is considered to be part of a given air compressor, regardless of whether the ancillary equipment is physically attached to the bare compressor, driver, or mechanical equipment at the time when the air compressor is distributed in commerce.

Bare compressor means the compression element and auxiliary devices (e.g., inlet and outlet valves, seals, lubrication system, and gas flow paths) required for performing the gas compression process, but does not include the driver; speed-adjusting gear(s); gas processing apparatuses and piping; or compressor equipment packaging and mounting facilities and enclosures.

Basic model means all units of a class of compressors manufactured by one manufacturer, having the same primary energy source, the same compressor motor nominal horsepower, and essentially identical electrical, physical, and functional (or pneumatic) characteristics that affect energy consumption and energy efficiency.

Brushless electric motor means a machine that converts electrical power into rotational mechanical power without use of sliding electrical contacts.

Compressor means a machine or apparatus that converts different types of energy into the potential energy of gas pressure for displacement and compression of gaseous media to any higher pressure values above atmospheric pressure and has a pressure ratio greater than 1.3.

Driver means the machine providing mechanical input to drive a bare compressor directly or through the use of mechanical equipment.

Fixed-speed compressor means an air compressor that is not capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor flow rate.

Full-load actual volume flow rate means the actual volume flow rate of the compressor at the full-load operating pressure.

Maximum full-flow operating pressure means the maximum discharge pressure at which the compressor is capable of operating, as determined in accordance with the test procedure prescribed in §431.344.

Mechanical equipment means any component of an air compressor that transfers energy from the driver to the bare compressor.

Compressor motor nominal horsepower means the motor horsepower of the electric motor, as determined in accordance with the applicable procedures in subpart B and subpart X of part 431, with which the rated air compressor is distributed in commerce.

Package isentropic efficiency means the ratio of power required for an ideal isentropic compression process to the actual packaged compressor power input used at a given load point, as determined in accordance with the test procedures prescribed in §431.344.

Package specific power means the compressor power input at a given load point, divided by the actual volume flow rate at the same load point, as determined in accordance with the test procedures prescribed in §431.344.

Positive displacement compressor means a compressor in which the admission and diminution of successive volumes of the gaseous medium are performed periodically by forced expansion and diminution of a closed space(s) in a working chamber(s) by means of displacement of a moving member(s) or by displacement and forced discharge of the gaseous medium into the high-pressure area.

Pressure ratio means the ratio of discharge pressure to inlet pressure, determined at full-load operating pressure in accordance with the test procedures prescribed in §431.344.

Reciprocating compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes are performed cyclically by straight-line alternating movements of a moving member(s) in a compression chamber(s).

Rotary compressor means a positive displacement compressor in which gas admission and diminution of its successive volumes or its forced discharge are performed cyclically by rotation of one or several rotors in a compressor casing.

Variable-speed compressor means an air compressor that is capable of adjusting the speed of the driver continuously over the driver operating speed range in response to incremental changes in the required compressor actual volume flow rate.

§431.343 Materials incorporated by reference.

(a) General. DOE incorporates by reference the following standard into part 431. The material listed has been approved for incorporation by reference by the Director of the Federal Register in accordance with 6 U.S.C. 522(a) and 1 CFR part 51. Any subsequent amendment to a standard by the standard-setting organization will not affect the DOE test procedures unless and until amended by DOE. Material is incorporated as it exists on the date of the approval and a notice of any change in the material will be published in the Federal Register. All approved material is available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202-741-6030, or go to: http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html. Also, this material is available for inspection at U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, Sixth Floor, 950 L'Enfant Plaza, SW., Washington, DC 20024, (202) 586-2945, or go to http://www1.eere.energy.gov/buildings/appliance_standards/. The following standards can be obtained from the sources below.

(b) ISO. International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland+41 22 749 01 11, www.iso.org.

(1) ISO Standard 1217:2009, ("ISO 1217:2009"), "Displacement compressors – Acceptance tests," sections 2, 3, and 4; subsections 5.2, 5.3, 5.4, 5.6, 5.9, 6.2(g), and 6.2(h); and subsections C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, C.4.4 of Annex C; approved 2009, IBR approved for appendix A to subpart T of part 431.

(2) [Reserved]

§431.344 Test procedure for measuring and determining energy consumption of compressors.

(a) Scope. (1) This section a test method that is applicable to a compressor that meets the following criteria:

(i) Is an air compressor,

(ii) Is a rotary or reciprocating compressor,

(iii) Is driven by a brushless electric motor,

(iv) Is distributed in commerce with a compressor motor nominal horsepower greater than or equal to 1 and less than or equal to 500 horsepower (hp), and

(v) Has a full-load operating pressure greater than or equal to 31 pounds per square inch gauge (psig) and less than or equal to 225 psig.

(b) Testing and Calculations. Determine the applicable full-load package isentropic efficiency ($\eta_{isen,FL}$), part-load package isentropic efficiency ($\eta_{isen,PL}$), package specific power, full-load operating pressure, full-load actual volume flow rate, and pressure ratio using the test procedure set forth in appendix A of this subpart T.

APPENDIX A TO SUBPART T OF PART 431 – UNIFORM TEST METHOD FOR CERTAIN AIR COMPRESSORS.

Note: Starting on **[INSERT DATE 180 DAYS AFTER DATE OF PUBLICATION OF THE FINAL RULE IN THE FEDERAL REGISTER]**, any representations made with respect to the energy use or efficiency of compressors subject to testing pursuant to 10 CFR 431.344 must be made in accordance with the results of testing pursuant to this appendix.

I. Measurements, Test Conditions, and Equipment Configuration

A. Measurement Equipment. For the purposes of measuring air compressor performance, the equipment necessary to measure flow rate, inlet and discharge pressure, temperature, condensate, power, and energy must comply with the equipment and accuracy requirements specified in ISO 1217:2009 sections 5.2, 5.3, 5.4, 5.6, 5.9, C.2.3, and C.2.4 of Annex C (incorporated by reference, see §431.343). In addition:

A.1. Electrical measurement equipment must be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency.

A.2. Any instruments used to measure a particular parameter specified in paragraph (A.1.) must have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the square root of the sum of the squares of individual instrument accuracies.

A.3. Any instruments used to directly measure the density of air must have an accuracy of ±1.0 percent of the measured value.

A.4. Any pressure measurement equipment used in a calculation of another variable (e.g., actual volume flow rate) must also meet all accuracy and measurement requirements of section 5.2 of ISO 1217:2009.

A.5. Any temperature measurement equipment used in a calculation of another variable (e.g., actual volume flow rate) must also meet all accuracy and measurement requirements of section 5.3 of ISO 1217:2009.

A.6. Where ISO 1217:2009 refers to "corrected volume flow rate," the term is deemed synonymous with the term "actual volume flow rate," as defined in section 3.4.1 of ISO 1217:2009.

B. Test Conditions and Configuration of Unit Under Test.

B.1. For both fixed-speed and variable-speed compressors, conduct testing in accordance with the test conditions, unit configuration, and specifications of subsections

6.2(g), 6.2(h), of ISO 1217:2009 and C.1.1, C.2.2, C.2.3, C.2.4, C.4.1, C.4.2.1, C.4.2.3, C.4.3.2, and C.4.4 of Annex C to ISO 1217:2009, Annex C (incorporated by reference, see §431.343). In addition, the test conditions and configuration must meet the following requirements:

B.1.1. Regarding the power supply: (1) Maintain the voltage within ±5 percent of the rated value of the motor, (2) maintain the frequency within ±1 percent of the rated value of the motor, (3) maintain the voltage unbalance of the power supply within ±3 percent of the rated values of the motor, and (4) maintain total harmonic distortion below 12 percent throughout the test.

B.1.2. Ambient Conditions. The ambient air temperature must be greater than or equal to 80°F and less than or equal to 90 °F for the duration of testing. There are no ambient condition requirements for inlet pressure or relative humidity.

B.1.3. Discharge Piping. The piping connected to the discharge orifice of the compressor must be of a diameter at least equal to that of the compressor discharge orifice to which it is connected. That piping must also be of a length at least fifteen times that diameter.

B.1.3.1. Discharge Piping Pressure Transducers. Transducers used to record compressor discharge pressure must be located on the discharge piping between 2 inches and 6 inches, inclusive, from the discharge orifice of the compressor.

C. Equipment Configuration.

C.1. All ancillary equipment that is distributed in commerce with the compressor under test must be present and installed for all tests specified in this appendix.

C.2. The inlet of the compressor under test must be open to the atmosphere and take in ambient air for all tests specified in this appendix.

C.3. The compressor under test must be set up according to all manufacturer instructions for normal operation (e.g., verify oil-level, connect all loose electrical connections, close off bottom of unit to floor, cover forklift holes).

II. Determination of Package Isentropic Efficiency, Package Specific Power, and Pressure Ratio

A. Data Collection and Analysis.

A.1. Stabilization. Record data (at each tested point) under steady-state conditions, which are achieved when the difference between two consecutive, unique, packaged compressor power input reading measurements, taken at a minimum of 10 seconds apart and measured per section C.2.4 of Annex C to ISO 1217:2009, is equal to or less than 300 watts.

A.2. Data Sampling and Frequency. At each load point, record a minimum of 16 unique measurements, collected over a minimum time of 15 minutes. Each consecutive measurement must be no more than 60 seconds apart, and not less than 10 seconds apart. The difference in packaged compressor power input between the maximum and minimum measurement must be equal to or less than 300 watts, as measured per section C.2.4 of Annex C to ISO 1217:2009. Each measurement within the 15-minute data recording time period must meet the requirements in this section; if one or more measurements do not meet the requirements then perform a new data recording of at least 16 new unique measurements collected over a minimum time of 15 minutes. Average the measurements to determine the value of each parameter to be used in subsequent calculations.

A.3. Calculations and Rounding. Perform all calculations using raw measured values. Round the final result for package isentropic efficiency to the thousandth (i.e., 0.001), for package specific power in kilowatt per 100 cubic feet per minute to the nearest hundredth (i.e., 0.01), for pressure ratio to the nearest tenth (i.e., 0.1), for full-load actual volume flow rate in actual cubic feet per minute to the nearest tenth (i.e., 0.1), and for full-load operating pressure in psig to the nearest integer (i.e., 1). All terms and quantities refer to values determined in accordance with the procedures set forth in this appendix for the tested unit.

B. Full-Load Operating Pressure and Full-Load Actual Volume Flow Rate. Determine the full-load operating pressure and full-load actual volume flow rate (referenced throughout this appendix) in accordance with the procedures prescribed in section III of this appendix.

C. Full-Load Isentropic Efficiency for Fixed- and Variable-Speed Air Compressors. Use this test method to test fixed-speed air compressors and variable-speed air compressors.

C.1. Maximum allowable deviation from specified load points. For the purposes of sections II.C.2, II.C.2.1, and II.C.2.2 of this appendix, maximum allowable deviations from the specified discharge pressure and volume rate in Tables C.1 and C.2 of Annex C of ISO 1217:2009 (incorporated by reference, see §431.343) apply. For the purposes of sections II.C.2, II.C.2.1, and II.C.2.2 of this appendix, the term "volume flow rate" in Table C.2 of Annex C of ISO 1217:2009 refers to the actual volume flow rate of the compressor under test.

C.2. Calculate the package isentropic efficiency at full-load operating pressure and 100 percent of full-load volume flow rate (full-load package isentropic efficiency) using the following equation:

$$\eta_{\mathrm{isen,FL}} = \eta_{\mathrm{isen,100\%}} = \frac{P_{\mathrm{isen,100\%}}}{P_{\mathrm{real,100\%}}}$$

Where:

$\eta_{\mathrm{isen,FL}} = \eta_{\mathrm{isen,100\%}}$ = package isentropic efficiency at full-load operating pressure and 100 percent of full-load actual volume flow rate,

$P_{isen,100\%}$ = isentropic power required for compression at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section II.C.2.1 of this appendix, and

$P_{real,100\%}$ = packaged compressor power input at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section II.C.2.2 of this appendix.

C.2.1. Calculate the isentropic power required for compression at full-load operating pressure and at 100 percent of full-load actual volume flow rate using the following equation:

$$P_{isen,100\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right]$$

Where:

$\dot{V}_{\mathbf{1\_m3/s}}$ = actual volume flow rate at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

p_2 = discharge pressure at full-load operating pressure and 100 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which, for the purposes of this test procedure, is 1.400.

C.2.2. Calculate packaged compressor power input at full-load operating pressure and 100 percent of full-load actual volume flow rate using the following equation:

$$P_{real,100\%} = K_5 \cdot P_{PR,100\%}$$

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009. For calculations of this variable use a value of 100 kPa for contractual inlet pressure, and

$P_{PR,100\%}$= packaged compressor power input reading at full-load operating pressure and 100 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

D. Part-Load Package Isentropic Efficiency for Variable-Speed Air Compressors. Use this test method to test variable-speed air compressors only.

D.1. For variable-speed compressors, calculate the part-load package isentropic efficiency using the following equation:

$$\eta_{isen,PL} = \omega_{40\%} \times \eta_{isen,40\%} + \omega_{70\%} \times \eta_{isen,70\%} + \omega_{100\%} \times \eta_{isen,100\%}$$

Where:

$\eta_{isen,PL}$ = part-load package isentropic efficiency for a variable-speed compressor,

$\eta_{isen,100\%}$ = package isentropic efficiency at full-load operating pressure, as determined in section II.C.2 of this appendix,

$\eta_{isen,70\%}$ = package isentropic efficiency at 70 percent of full-load actual volume flow rate, as determined in section II.D.3 of this appendix,

$\eta_{isen,40\%}$ = package isentropic efficiency at 40 percent of full-load actual volume flow rate, as determined in section II.D.4 of this appendix,

$\omega_{40\%}$ = weighting at 40 percent of full-load actual volume flow rate and is 0.25,

$\omega_{70\%}$ = weighting at 70 percent of full-load actual volume flow rate and is 0.50, and

$\omega_{100\%}$ = weighting at 100 percent of full-load actual volume flow rate and is 0.25.

D.2. Maximum allowable deviation from specified load points. For the purposes of sections II.D.3, II.D.3.1, II.D.3.2, II.D.4, II.D.4.1 and II.D.4.2 of this appendix, the maximum allowable deviations from the specified volume flow rate specified in Table C.2 of Annex C of ISO 1217:2009 (incorporated by reference, see §431.343) apply. For the purposes of sections II.D.3, II.D.3.1, II.D.3.2, II.D.4, II.D.4.1 and II.D.4.2 of this appendix, the term volume flow rate in Table C.2 of Annex C of ISO 1217:2009 refers to the actual volume flow rate of the compressor under test.

D.3. To determine the package isentropic efficiency at 70 percent of full-load actual volume flow rate, adjust the speed of the driver to reach the specified load point (70 percent of full-load actual volume flow rate). Calculate package isentropic efficiency at 70 percent of full-load actual volume flow rate using the following equation:

$$\eta_{isen,70\%} = \frac{P_{isen,70\%}}{P_{real,70\%}}$$

Where:

$\eta_{isen,70\%}$ = package isentropic efficiency at 70 percent of full-load actual volume flow rate,

$P_{isen,70\%}$ = isentropic power required for compression at 70 percent of full-load actual volume flow rate, as determined in section II.D.3.1 of this appendix, and

$P_{real,70\%}$ = packaged compressor power input at 70 percent of full-load actual volume flow rate, as determined in section II.D.3.2 of this appendix.

D.3.1. Calculate the isentropic power required for compression at 70 percent of full-load actual volume flow rate using the following equation:

$$P_{isen,70\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right]$$

Where:

$\dot{V}_{\mathbf{1\_m3/s}}$ = actual volume flow rate at 70 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

p_2 = discharge pressure at 70 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which for the purposes of this test procedure is 1.400.

D.3.2. Calculate packaged compressor power input at 70 percent of full-load actual volume flow rate using the following equation:

$$P_{real,70\%} = K_5 \cdot P_{PR,70\%}$$

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009. For calculations of this variable use a value of 100 kPa for contractual inlet pressure, and

$P_{PR,70\%}$= packaged compressor power input reading at full-load operating pressure and 70 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

D.4. To determine the package isentropic efficiency at 40 percent of full-load actual volume flow rate, adjust the speed of the driver to reach the specified load point (40 percent of full-load actual volume flow rate). Calculate package isentropic efficiency at 40 percent of full-load actual volume flow rate using the following equation:

$$\eta_{isen,40\%} = \frac{P_{isen,40\%}}{P_{real,40\%}}$$

Where:

$\eta_{isen,40\%}$ = package isentropic efficiency at 40 percent of full-load actual volume flow rate,

$P_{isen,40\%}$ = isentropic power required for compression at 40 percent of full-load actual volume flow rate, as determined in section II.D.4.1 of this appendix, and

$P_{real,40\%}$ = packaged compressor power input at 40 percent of full-load actual volume flow rate, as determined in section II.D.4.2 of this appendix.

D.4.1. Calculate the isentropic power required for compression at 40 percent of full-load actual volume flow rate using the following equation:

$$P_{isen,40\%} = \dot{V}_{1\_m3/s} \cdot p_1 \frac{\kappa}{(\kappa - 1)} \cdot \left[\left(\frac{p_2}{p_1} \right)^{\frac{\kappa - 1}{\kappa}} - 1 \right]$$

Where:

$\dot{V}_{\mathbf{1\_m3/s}}$ = actual volume actual volume flow rate at 40 percent of full-load actual volume flow rate, as determined in section C.4.2.1 of annex C of ISO 1217:2009 (cubic meters per second) with no corrections made for shaft speed,

p_1 = atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa),

p_2 = discharge pressure at 40 percent of full-load actual volume flow rate, determined in accordance with section 5.2 of ISO 1217:2009 (Pa), and

κ = isentropic exponent (ratio of specific heats) of air, which for the purposes of this test procedure is 1.400.

D.4.2. Calculate packaged compressor power input at 40 percent of full-load actual volume flow rate using the following equation:

$$P_{real,40\%} = K_5 \cdot P_{PR,40\%}$$

Where:

K_5= correction factor for inlet pressure and pressure ratio, as determined in section C.4.3.2 of annex C to ISO 1217:2009. For calculations of this variable use a value of 100 kPa for contractual inlet pressure, and

$P_{PR,40\%}$= packaged compressor power input reading at full-load operating pressure and 40 percent of full-load actual volume flow rate, as determined in section C.2.4 of annex C to ISO 1217:2009 (watts).

E. Determination of Package Specific Power. For both fixed- and variable-speed air compressors, determine the package specific power, at any load point, using the equation for specific energy consumption in section C.4.4 of annex C of ISO 1217:2009 (incorporated by reference, see §431.343) and other values measured pursuant to this appendix.

F. Determination of Pressure Ratio.

F.1. Maximum allowable deviation from specified load points. For the purposes of section II.F.2 of this appendix, do not exceed the maximum allowable deviations from the specified discharge pressure and volume flow rate specified in Tables C.1 and C.2 of Annex C of ISO 1217:2009 (incorporated by reference, see §431.343). For the purposes of sections II.F.2 of this appendix, the term volume flow rate, in Table C.2 of Annex C of ISO 1217: 2009 refers to the actual volume flow rate of the compressor under test.

F.2. Pressure ratio, as defined in §431.342, is determined at full-load operating pressure. Calculate pressure ratio using the following equation:

$$\mathrm{PR} = \frac{\mathrm{p}_2}{\mathrm{p}_1}$$

Where:

PR = pressure ratio,

p_1 = atmospheric pressure, as determined in section 5.2.2 of ISO 1217:2009 (Pa), and

p_2 = discharge pressure at full-load operating pressure, determined in accordance with section 5.2 of ISO 1217:2009 (Pa).

III. Method to Determine Maximum Full-Flow Operating Pressure, Full-Load Operating Pressure, and Full-Load Actual Volume Flow Rate.

A. Principal Strategy

The principal strategy of this method is to incrementally increase discharge pressure by 2 psig relative to a starting point, and identify the maximum full-flow operating pressure at which the compressor is capable of operating. The maximum discharge pressure achieved is the maximum full-flow operating pressure. The full-load operating pressure and full-load actual volume flow rate are determined based on the maximum full-flow operating pressure.

B. Pre-test Instructions

B.1. Safety

For the method presented in section III.C.1 of this appendix, only test discharge pressure within the safe operating range of the compressor, as specified by the manufacturer in the installation and operation manual shipped with the unit. Make no changes to safety limits or equipment. Do not violate any manufacturer-provided, motor operational guidelines for normal use, including any restriction on instantaneous and continuous input power draw and output shaft power (e.g., electrical rating and service factor limits).

B.2. Adjustment of Discharge Pressure

B.2.1. If the air compressor is not equipped, as distributed in commerce by the manufacturer, with any mechanism to adjust the maximum discharge pressure output limit, proceed to section III.B.3 of this appendix.

B.2.2. If the air compressor is equipped, as distributed in commerce by the manufacturer, with any mechanism to adjust the maximum discharge pressure output limit, then adjust this mechanism to the maximum pressure allowed, according to the manufacturer's operating instructions for these mechanisms. Mechanisms to adjust discharge pressure may include, but are not limited to, onboard digital or analog controls, and user-adjustable inlet valves.

B.3. Driver-speed

If the unit under test is a variable-speed compressor, maintain maximum driver speed throughout the test. If the unit under test is a fixed-speed compressor with a multi-speed driver, maintain driver speed at the maximum speed throughout the test.

B.4. Measurements and Tolerances

B.4.1. Recording

Record data by electronic means such that the requirements of section B.4.5 of section III of this appendix are met.

B.4.2. Discharge Pressure

Measure discharge pressure in accordance with section 5.2 of ISO 1217:2009 (incorporated by reference, see §431.343). Express compressor discharge pressure in pounds per square inch, gauge (“psig”), in reference to ambient conditions, and record it to the nearest integer. Specify targeted discharge pressure points in integer values only. The maximum allowable measured deviation from the targeted discharge pressure at each tested point is ±1 psig.

B.4.3. Actual Volume Flow Rate

Measure actual volume flow rate in accordance with section C.4.2.1 of annex C of ISO 1217:2009 (where it is called “corrected volume flow rate”) with no corrections made for shaft speed. Express compressor actual volume flow rate in actual cubic feet per minute at inlet conditions (“acfm”).

B.4.4. Stabilization.

Record data (at each tested point) under steady-state conditions, which are achieved when the difference between two consecutive, unique, packaged compressor power input reading measurements, taken at a minimum of 10 seconds apart and measured per section C.2.4 of Annex C to ISO 1217:2009, is equal to or less than 300 watts.

B.4.5. Data Sampling and Frequency.

At each load point, record a minimum of two separate measurements, collected at a minimum of 10 seconds apart. Each consecutive measurement must meet the stabilization requirement established in section III.B.4.4 of this appendix. Average the measurement to determine the value of each parameter to be used in subsequent calculations.

B.5 Adjusting System Back-Pressure

Set up the unit under test so that back-pressure on the unit can be adjusted (e.g., by valves) incrementally, causing the measured discharge pressure to change, until the compressor is in an unloaded condition.

B.6 Unloaded Condition

A unit is considered to be in an unloaded condition if capacity controls on the unit automatically reduce the actual volume flow rate from the compressor (e.g., shutting the motor off, or unloading by adjusting valves).

C. Test Instructions

C.1. Adjust the back-pressure of the system so the measured discharge pressure is 90 percent of the certified maximum full-flow operating pressure, rounded to the nearest integer, in psig. If the expected maximum full-flow operating pressure is not known, then adjust the back-pressure of the system so that the measured discharge pressure is 75 psig. Allow the unit to remain at this setting for 15 minutes to allow the unit to thermally stabilize. Then measure and record discharge pressure and actual volume flow rate at the starting pressure.

C.2. Adjust the back-pressure of the system to increase the discharge pressure by 2 psig from the previous value, allow the unit to remain at this setting for a minimum of 2 minutes, and proceed to section IV.C.3 of this appendix.

C.3. If the unit is now in an unloaded condition, end the test and proceed to section III.C.4 of this appendix. If the unit is not in an unloaded condition, measure discharge pressure and actual volume flow rate, and repeat section III.C.2 of this appendix.

C.4. Of the discharge pressures recorded under stabilized conditions in sections III.C.1 through III.C.3 of this appendix, identify the largest. This is the maximum full-flow operating pressure. Determine the full-load operating pressure as a self-declared value greater than or equal to 90 percent of and less than or equal to the measured maximum full-flow operating pressure. The full-load actual volume flow rate is the actual volume flow rate measured at the full-load operating pressure.

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