This document, concerning the Energy Conservation Program: Test Procedure for Pumps, is a rulemaking action issued by the Department of Energy. Though it is not intended or expected, should any discrepancy occur between the document posted here and the document published in the *Federal Register*, the *Federal Register* publication controls. This document is being made available through the Internet solely as a means to facilitate the public's access to this document."

[6450-01-P]

DEPARTMENT OF ENERGY

10 CFR Parts 429 and 431

[Docket No. EERE-2013-BT-TP-0055]

RIN 1905-AD50

Energy Conservation Program: Test Procedure for Pumps

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

ACTION: Final rule.

SUMMARY: On April 1, 2015, the U.S. Department of Energy (DOE) issued a notice of proposed rulemaking (NOPR) to establish new definitions and a new test procedure for pumps. That proposed rulemaking serves as the basis for this final rule. This final rule establishes a new test procedure for pumps, as well as associated definitions and parameters that establish the scope of applicability of the test procedure. Specifically, the pumps test procedure adopted in this final rule incorporates by reference the test procedure from the Hydraulic Institute (HI)—standard 40.6–2014, “Methods for Rotodynamic Pump Efficiency Testing”—with several clarifications and modifications, related to measuring the hydraulic power, shaft power, and electric input power of pumps, inclusive of electric motors and any continuous or non-continuous controls. The new pumps test procedure will be used to determine the constant load pump energy index (PEI_{CL}) for pumps sold without continuous or non-continuous controls and the variable load pump energy index (PEI_{VL}) for pumps sold with continuous or non-continuous

controls. The final rule incorporates certain recommendations made by the commercial and industrial pumps (CIP) Working Group, which was established under the Appliance Standards Rulemaking Federal Advisory Committee (ASRAC), as well as comments submitted by interested parties in response to the April 2015 pumps test procedure NOPR.

DATES: The effective date of this rule is **[INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER]**. Compliance with the final rule will be mandatory for representations of PEI_{CL}, PEI_{VL}, the constant load pump energy rating (PER_{CL}), and the variable load pump energy rating (PER_{VL}) made on or after **[INSERT DATE 180 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER].** The incorporation by reference of certain publications listed in this rule is approved by the Director of the Federal Register as of [**INSERT DATE 30 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER**].

ADDRESSES: The docket, which includes Federal Register notices, public meeting attendee lists and transcripts, comments, and other supporting documents/materials, is available for review at regulations.gov. All documents in the docket are listed in the www.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/44.

This web page contains a link to the docket for this notice on the regulations.gov site. The www.regulations.gov web page contains simple instructions on how to access all documents, including public comments, in the docket.

For further information on how to review the docket, contact Ms. Brenda Edwards at (202) 586-2945 or by email: Brenda.Edwards@ee.doe.gov.

FOR FURTHER INFORMATION CONTACT:

Ms. Ashley Armstrong, 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) 586-6590. E-mail: Pumps2013TP0055@ee.doe.gov.

Jennifer Tiedeman, U.S. Department of Energy, Office of the General Counsel, GC-33, 1000 Independence Avenue, SW., Washington, DC, 20585-0121. Telephone: (202) 287-6111. E-mail: Jennifer.Tiedeman@hq.doe.gov.

SUPPLEMENTARY INFORMATION:

This final rule incorporates by reference into 10 CFR part 431 the following industry standards:

(1) FM Class Number 1319, “Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type),” approved January 2015.

Copies of FM Class Number 1319 can be obtained from: FM Global, 1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062, (781) 762-4300, or by visiting www.fmglobal.com.

(2) American National Standards Institute (ANSI)/HI 1.1-1.2–2014 ("ANSI/HI 1.1-1.2–2014"), "American National Standard for Rotodynamic Centrifugal Pumps for Nomenclature and Definitions;" approved October 30, 2014, sections 1.1, "Types and nomenclature," and 1.2.9, "Rotodynamic pump icons."

(3) ANSI/HI 2.1-2.2–2014 ("ANSI/HI 2.1-2.2–2014 "), "American National Standard for Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions," approved April 8, 2014, section 2.1, "Types and nomenclature."

(4) HI 40.6–2014, ("HI 40.6–2014") "Methods for Rotodynamic Pump Efficiency Testing," (except for section 40.6.5.3, "Test report;" Appendix A, section A.7, "Testing at temperatures exceeding 30 °C (86 °F);" and Appendix B, "Reporting of test results (normative);") copyright 2014.

Copies of ANSI/HI 1.1-1.2–2014, ANSI/HI 2.1-2.2–2014, and HI 40.6–2014 can be obtained from: the Hydraulic Institute at 6 Campus Drive, First Floor North, Parsippany, NJ 07054-4406, (973) 267-9700, or by visiting www.pumps.org.

(5) National Fire Protection Association (NFPA) 20-2016, “Standard for the Installation of Stationary Pumps for Fire Protection,” 2016 Edition, approved June 15, 2015.

Copies of NFPA 20-2016 can be obtained from: the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169, (617) 770-3000, or by visiting www.nfpa.org.

(6) UL 488, (“ANSI/UL 448-2013”), “Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service,” 10th Edition, June 8, 2007, including revisions through July 12, 2013.

Copies of ANSI/UL448-2013 can be obtained from: UL, 333 Pfingsten Road, Northbrook, IL 60062, (847) 272-8800, or by visiting http://ul.com.

This material is also 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 at http://energy.gov/eere/buildings/appliance-and-equipment-standards-program.

See section IV.N. for additional information about these standards.

Table of Contents

I. Authority and Background

Pumps are included in the list of "covered equipment" for which the U.S. Department of Energy (DOE) is authorized to establish and amend energy conservation standards and test procedures. (42 U.S.C. 6311(1)(A)) However, there are not currently any Federal energy conservation standards or test procedures for pumps. The following sections discuss DOE's authority to establish test procedures for pumps and relevant background information regarding DOE's consideration of test procedures for this equipment.

A. Authority

The Energy Policy and Conservation Act of 1975 (EPCA), Public Law 94-163, as amended by Public Law 95-619, Title IV, Sec. 441(a), established the Energy Conservation Program for Certain Industrial Equipment under Title III, Part C (42 U.S.C. 6311-6317, as codified)[1,2] Included among the various types of industrial equipment addressed by EPCA are pumps, the subject of this notice. (42 U.S.C. 6311(1)(A))

Under EPCA, the energy conservation program consists essentially of four parts: (1) testing, (2) labeling, (3) Federal energy conservation standards, and (4) certification and enforcement procedures. The testing requirements consist of test procedures that manufacturers of covered products must use as the basis for (1) certifying to DOE that

[1] For editorial reasons, Part C was codified as Part A-1 in the U.S. Code.
[2] All references to EPCA in this document refer to the statute as amended through the Energy Efficiency Improvement Act of 2015, Pub. L. 114-11 (April 30, 2015).

their products comply with the applicable energy conservation standards adopted under EPCA, (42 U.S.C. 6295(s) and 6316(a)(1)), and (2) making representations about the efficiency of that equipment. (42 U.S.C. 6314(d)) Similarly, DOE must use these test procedures to determine whether the products comply with any relevant standards promulgated under EPCA.

DOE is authorized to prescribe energy conservation standards and corresponding test procedures for statutorily covered equipment such as pumps. While DOE is currently evaluating whether to establish energy conservation standards for pumps (Docket No. EERE-2011-BT-STD-0031), DOE must first establish a test procedure that measures the energy use, energy efficiency, or estimated operating costs of such equipment. See, generally, 42 U.S.C. 6295(r) and 6316(a).

Under 42 U.S.C. 6314, EPCA sets forth the criteria and procedures DOE must follow when prescribing or amending test procedures for covered equipment. EPCA provides that any test procedures prescribed or amended under this section shall be reasonably designed to produce test results that measure energy efficiency, energy use or estimated annual operating cost of a covered product during a representative average use cycle or period of use, and shall not be unduly burdensome to conduct. (42 U.S.C. 6314(a)(2))

In addition, before prescribing any final test procedures, DOE must publish proposed test procedures and offer the public an opportunity to present oral and written comments on them. (42 U.S.C. 6314(b)(1)-(2))

In this final rule, DOE is establishing a test procedure for pumps concurrent with its ongoing energy conservation standards rulemaking for this equipment (See Docket No. EERE-2011-BT-STD-0031). As discussed further in section I.B, DOE published a notice of proposed rulemaking (NOPR) on April 1, 2015 presenting and requesting public comment on DOE's proposals related to pumps definitions, metric, and test procedure requirements (April 2015 pump test procedure NOPR). 80 FR 17586.

The pumps test procedure adopted in this final rule includes methods required to (1) measure the performance of the covered equipment and (2) use the measured results to calculate a pump energy index (PEI_{CL} for pumps sold without continuous or non-continuous controls or PEI_{VL} for pumps sold with continuous or non-continuous controls) to represent the power consumption of the pump, inclusive of a motor and any continuous or non-continuous controls, normalized with respect to the performance of a minimally compliant pump. In this final rule, DOE is also establishing the specific styles and characteristics of pumps to which the test procedure applies.

Manufacturers will be required to make all representations of pump efficiency, overall (wire-to-water) efficiency, bowl efficiency, driver power input, pump power input (brake or shaft horsepower), and/or pump power output (hydraulic horsepower) using methods that will generate values consistent with the DOE test procedure beginning 180 days after the publication date of this final rule in the Federal Register. Manufacturers also will be required to use the new test procedure and metric when making representations regarding the PEI_{CL}, PEI_{VL}, PER_{CL}, or PER_{VL} of covered equipment 180 days after the publication date of any applicable energy conservation standards final rule in the Federal Register. However, DOE notes that certification of compliance with any energy conservation standards for pumps would not be required until the compliance date of any final rule establishing such energy conservation standards. See 42 U.S.C. 6314(d) and Docket No. EERE-2011-BT-STD-0031.

B. Background

DOE does not currently regulate pumps. In 2011, DOE issued a Request for Information (RFI) to gather data and information related to pumps in anticipation of initiating rulemakings to formally consider test procedures and energy conservation standards for this equipment. 76 FR 34192 (June 13, 2011). In February 2013, DOE published a Notice of Public Meeting and Availability of the Framework document to initiate an energy conservation standard rulemaking for pumps (78 FR 7304 Feb. 1, 2013) and held a public meeting to discuss the Framework document (the "pumps Framework public meeting").

Following the pumps Framework public meeting, DOE convened a Commercial and Industrial Pumps Working Group ("CIP Working Group" or, in context, "Working Group") through the Appliance Standards Rulemaking Federal Advisory Committee

(ASRAC) to negotiate standards and test procedures for pumps as an alternative to the traditional notice and comment rulemaking process that DOE had already begun. (Docket No. EERE-2013-BT-NOC-0039)[3] The CIP Working Group commenced negotiations at an open meeting on December 18 and 19, 2013, and held six additional meetings and two webinars to discuss definitions, metrics, test procedures, and standard levels for pumps.[4] The CIP Working Group concluded its negotiations on June 19, 2014, with a consensus vote to approve a term sheet containing recommendations to DOE on appropriate standard levels for pumps as well as recommendations addressing issues related to the metric and test procedure for pumps ("Working Group recommendations").[5] Subsequently, ASRAC voted unanimously to approve the Working Group recommendations during a July 7, 2014 webinar.

Following approval of the Working Group recommendations, DOE published a NOPR implementing the recommendations of the CIP Working Group[6] and proposing a new test procedure for pumps, as well as associated definitions and parameters to establish the applicability of the test procedure (April 2015 pump test procedure NOPR). 80 FR 17586 (April 1, 2015). On April 29, 2015, DOE held a public meeting to discuss

---

[3] Information on the ASRAC, the CIP Working Group, and meeting dates is available at http://energy.gov/eere/buildings/appliance-standards-and-rulemaking-federal-advisory-committee.

[4] Details of the negotiation sessions can be found in the public meeting transcripts that are posted to the docket for the Working Group (http://www.regulations.gov/#!docketDetail;D=EERE-2013-BT-NOC-0039).

[5] The term sheet containing the Working Group recommendations is available in the CIP Working Group's docket. (Docket No. EERE-2013-BT-NOC-0039, No. 92) The ground rules of the CIP Working Group define consensus as no more than two negative votes. (Docket No. EERE-2013-BT-NOC-0039, No. 18 at p. 2) Concurrence was assumed if a voting member was absent, and overt dissent was only evidenced by a negative vote. Abstention was not construed as a negative vote.

[6] DOE's proposals in the April 2015 pumps test procedure NOPR reflect the intent of the CIP Working Group recommendations. However, DOE proposed some slight modifications and significant additional detail to ensure the technical integrity, accuracy, repeatability, and enforceability of the pumps test procedure and scope.

and request public comment on the April 2015 pumps test procedure NOPR (April 2015 NOPR public meeting).

DOE's test procedure for pumps, adopted in this final rule, reflects certain recommendations of the CIP Working Group, as well as input from interested parties received in response to the April 2015 pumps test procedure NOPR. Provisions of this final rule that are directly pertinent to any of the 14 approved Working Group recommendations will be specified with a citation to the specific recommendation number (for example: Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #X at p. Y). Additionally, in developing the provisions of this final rule, DOE also has referenced discussions from the CIP Working Group meetings regarding potential actions or comments that may not have been formally approved as part of the Working Group recommendations. These references to discussions or suggestions of the CIP Working Group not found in the Working Group recommendations will have a citation to meeting transcripts (for example: Docket No. EERE-2013-BT-NOC-0039, No. X at p. Y).

Finally, in this final rule, DOE responds to all comments received from interested parties in response to the proposals presented in the April 2015 pumps test procedure NOPR, either during the April 2015 NOPR public meeting or in subsequent written comments. In response to the April 2015 pumps test procedure NOPR, DOE received eight written comments in addition to the verbal comments made by interested parties during the April 2015 NOPR public meeting. The commenters included: Wilo USA, LLC (Wilo); the Hydraulic Institute (HI); the National Electrical Manufacturers

Association (NEMA); the Appliance Standards Awareness Project (ASAP), Natural Resources Defense Council (NRDC), Northwest Energy Efficiency Alliance (NEEA), and Northwest Power and Conservation Council (NPCC), collectively referred to herein as the energy efficiency advocates (EEAs); the Air-Conditioning, Heating, & Refrigeration Institute (AHRI); the Association of Pool & Spa Professionals (APSP); Pacific Gas and Electric Company (PG&E), Southern California Gas Company (SCG), Southern California Edison (SCE), and San Diego Gas and Electric Company (SDG&E), collectively referred to herein as the CA IOUs. DOE will identify comments received in response to the April 2015 pumps test procedure NOPR by the commenter, the number of document as listed in the docket maintained at www.regulations.gov (Docket No. EERE-2013-BT-TP-0055), and the page number of that document where the comment appears (for example: HI, No. 8 at p. 4). If a comment was made verbally during the NOPR public meeting, DOE will also specifically identify those as being located in the NOPR public meeting transcript (for example: HI, NOPR public meeting transcript, No. 7 at p. 235). This final rule also contains comments submitted in response to the pumps energy conservation standards rulemaking (Docket No. EERE-2011-BT-STD-0031) and such comments will be identified with that docket number.

II. Summary of the Final Rule

In this final rule, DOE is establishing a new subpart Y to part 431 of Title 10 of the Code of Federal Regulations that contains definitions and a test procedure applicable to pumps. This final rule also contains sampling plans for pumps for the purposes of making representations regarding the energy consumption of applicable pumps and demonstrating compliance with any energy conservation standards that DOE adopts.

DOE notes that equipment meeting the pump definition is already covered equipment. In this final rule, DOE is establishing definitions for the term pump, certain pump components, and several categories and configurations of pumps. While the range of equipment included in DOE's definition of pump is broad, the test procedure established by this rulemaking is limited to a specific scope of pumps, as described in section III.A of this final rule; specifically certain kinds of rotodynamic pumps[7] for which standards are being considered in DOE's energy conservation standards rulemaking. (Docket No. EERE-2011-BT-STD-0031)

DOE's approach adopted in this final rule establishes a new metric, the pump energy index (PEI), to rate the energy performance of pumps subject to this test procedure. The test procedure contains methods for determining constant load pump energy index (PEI_{CL}) for pumps sold without continuous or non-continuous controls and the variable load pump energy index (PEI_{VL}) for pumps sold with either continuous or non-continuous controls. Both PEI_{CL} and PEI_{VL} describe the weighted average performance of the rated pump at specific load points, normalized with respect to the performance of a minimally compliant pump without controls.

[7] A rotodynamic (or centrifugal) pump is a kinetic machine that continuously imparts energy to the pumped fluid by means of a rotating impeller, propeller, or rotor. This kind of pump is in contrast to positive-displacement pumps, which have an expanding cavity on the suction side and a decreasing cavity on the discharge side that move a constant volume of fluid for each cycle of operation.

The test procedure contains methods to determine the appropriate index for all equipment for which this test procedure applies using either calculation-based methods and/or testing-based methods. While both methods include some amount of testing and some amount of calculation, the terms "calculation-based" and "testing-based" are used to distinguish between methods in which the input power to the pump is determined either by (a) measuring the bare pump shaft input power[8] and calculating efficiency, or losses, of the motor and any continuous control[9] (i.e., calculation-based method) or (b) measuring the input power to the driver,[10] or motor, and any continuous or non-continuous controls[11] for a given pump directly (i.e., testing-based method). For both the testing-based and calculation-based approaches, the test procedure for pumps established in this final rule is based on the test methods contained in HI Standard 40.6–2014, "Methods for Rotodynamic Pump Efficiency Testing," ("HI 40.6–2014"), with slight modifications as noted in section III.C.2.

The test procedure also prescribes the specific categories and configurations of pumps to which the calculation-based and testing-based methods are applicable. As discussed further in section III.E.2, the testing-based methods are applicable to all pumps

---

[8] The term "pump shaft input power" is referred to as "pump power input" in HI 40.6-2014. The term "pump shaft input power" is used synonymously with that term in this document.

[9] DOE notes that for non-continuous controls, as defined in section III.E.1.c, PEI_{VL} can only be determined using a "testing-based" method. If a calculation-based method is desired, the pump would instead be rated as a pump sold with a motor and without speed controls using the PEI_{CL} metric. See section III.E.1.c for further discussion.

[10] The input power to the driver is referred to as "driver power input" in HI 40.6-2014. The term "input power to the driver" is used synonymously with that term in this document.

[11] In the case wherein a pump is sold with a motor equipped with either continuous or non-continuous controls and is rated using the testing-based method, the input power to the pump would be determined as the input power to the continuous or non-continuous control. See section III.E.2.c.

that are subject to the test procedure, while the calculation-based methods are only applicable to (1) pumps sold with neither a motor nor controls (i.e., “bare pump,” discussed later in section III.A.1.a), (2) pumps sold with motors that are subject to DOE’s energy conservation standards for electric motors[12] (with or without continuous controls), and (3) pumps sold with submersible motors (with or without continuous controls).

Regardless of the metric (i.e., PEI_{CL} versus PEI_{VL}) or test method (i.e., calculation-based versus testing-based), the results for the given pump are divided by the calculated input power to the motor for a hypothetical pump that serves an identical hydraulic load and minimally complies with any energy conservation standards that DOE may set as a result of the ongoing standards rulemaking. (Docket No. EERE-2011-BT-STD-0031) This normalized metric results in a value that is indexed to the standard (i.e., a value of 1.0 for a pump that is minimally compliant, and a value less than 1.0 for a pump that is less consumptive than the maximum the standard allows).

This final rule also establishes requirements regarding the sampling plan and representations for covered pumps at subpart B of part 429 of Title 10 of the Code of Federal Regulations. The sampling plan requirements are similar to those for several other types of commercial equipment and are appropriate for pumps based on the expected range of measurement uncertainty and manufacturing tolerances for this equipment. For those pumps addressed by this test procedure, DOE is also specifying the

[12] All references to “motors that are subject to DOE’s energy conservation standards for electric motors” refer to those motors that are subject to the energy conservation standards for electric motors at 431.25(g) (as established in the May 2014 medium electric motor energy conservation standard final rule. 79 FR 30933 (May 29, 2014)). See section III.D.1 and III.E.1 for more discussion.

energy consumption or energy efficiency representations that may be made, in addition to the regulated metric (PEI_{CL} or PEI_{VL}).

Beginning on the compliance date for any energy conservation standards that DOE may set, all pumps within the scope of those energy conservation standards would be required to be tested in accordance with subpart Y of part 431 and must have their testing performed in a manner consistent with the applicable sampling requirements. Manufacturers must make all representations of pump efficiency, overall (wire-to-water) efficiency, bowl efficiency, driver power input, pump power input (brake or shaft horsepower), and/or pump power output (hydraulic horsepower) using methods that will generate values consistent with the DOE test procedure beginning 180 days after the publication date of this final rule in the Federal Register. Similarly, all representations regarding PEI_{CL}, PEI_{VL}, PER_{CL}, or PER_{VL} would be required to be made based on values consistent with the adopted pump test procedure 180 days after the publication date of any final rule establishing energy conservation standards for those pumps that are addressed by the test procedure. See 42 U.S.C. 6314(d). DOE understands that manufacturers of pumps likely have historical test data (e.g., existing pump curves) which were developed with methods consistent with the DOE test procedure being adopted in this final rule. DOE notes that it does not expect manufacturers to regenerate all of the historical test data unless the rating resulting from the historical methods, which is based on the same methodology being adopted in this final rule, would no longer be valid.

III. Discussion

This final rule places a new test procedure for pumps and related definitions in a new subpart Y of part 431, and adds new sampling plans and reporting requirements for this equipment in a new section 429.59 of 10 CFR part 429. Subpart Y contains definitions, materials incorporated by reference, and the test procedure for certain categories and configurations of pumps established as a result of this rulemaking, as well as any energy conservation standards for pumps resulting from the ongoing energy conservation standard rulemaking, as shown in Table III.1. (Docket No. EERE-2011-BT-STD-0031)

Table III.1 Summary of Relevant Provisions Addressed in this Final Rule, their Location within the Code of Federal Regulations, and the Applicable Preamble Discussion

Location	Proposal	Summary of Additions	Applicable Preamble Discussion
10 CFR 429.59*	Sampling Plan	Number of pumps to be tested to rate a pump basic model and calculation of rating	Section III.G
10 CFR 431.461	Purpose and Scope	Scope of pump regulations, as well as the proposed test procedure and associated energy conservation standards	Section III.A
10 CFR 431.462	Definitions	Definitions pertinent to establishing equipment classes and testing applicable classes of pumps	Section III.A
10 CFR 431.463	Incorporation by Reference	Description of industry standards incorporated by reference in the DOE test procedure or related definitions	Sections III.A and III.C
10 CFR 431.464 and Appendix A to Subpart Y of Part 431	Test Procedure	Instructions for determining the PEI_{CL} or PEI_{VL} for applicable classes of pumps	Sections III.B, III.C, III.D, and III.E
10 CFR 431.466	Energy Conservation Standards	Energy conservation standard for applicable classes of pumps, in terms of PEI and associated C-Value	Section III.A and Docket EERE-2011-BT-STD-0031

* Note: DOE is also making minor modifications to 10 CFR 429.2; 429.11(a) and (b); 429.12(b)(13); 429.70; 429.72; 429.102; and 429.134 to apply the general sampling requirements established in these sections to the equipment-specific sampling requirements for pumps at 10 CFR 429.59.

The following sections discuss DOE's new provisions regarding testing and sampling requirements for pumps, including:

1) scope,
2) rating metric,
3) determination of pump performance,
4) determination of motor efficiency,
5) test methods for different combinations of bare pumps, drivers and controls,
6) representations, and
7) sampling plans.

These sections also present any pertinent comments DOE received in response to the April 2015 pumps test procedure NOPR or the parallel pumps energy conservation standards rulemaking (Docket No. EERE-2011-BT-STD-0031), as well as DOE's responses to those comments and the resulting changes to the test procedure as proposed in the NOPR.

A. Scope

The term "pump" is listed as a type of covered equipment under EPCA; however, that term is undefined. See 42 U.S.C. 6311(1)(A). In the April 2015 pumps test procedure NOPR, consistent with recommendations from the CIP Working Group (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendations #4 and 6–8 at pp. 2–4), DOE proposed definitions for the term pump, as covered equipment, and related components of pumps. 80 FR 17586, 17591 (April 1, 2015). In addition, DOE proposed to define which pumps would need to be tested using the test procedure established in this rulemaking by applying three criteria: (1) the equipment category; (2) the application; and (3) applicable performance specifications—i.e., horsepower (hp), flow rate, head, design temperature, and speed restrictions. Id.

In response to DOE's proposed definitions and scope of the test procedure for pumps, HI commented that it detected no inconsistencies with the scope of the pump test procedure and energy conservation standard rulemakings. (HI, No. 8 at p. 4)

DOE's criteria for establishing which pumps will be subject to the test procedure, including any additional comments received by interested parties on those particular topics, are discussed in sections III.A.1 through III.A.6, respectively.

1. Definitions Related to the Scope of Covered Pumps

To help explain the scope for this rule and the manner in which both the procedure and related standards will be applied to different pump configurations and categories of pumps, the aforementioned definitions for pump, certain pump components, and other specific pump characteristics, are discussed in the following subsections.

a. Pumps and Related Components

As part of its collective efforts to help DOE craft an appropriate regulatory approach to pumps, the CIP Working Group made a series of recommendations regarding a variety of potential definitions that would define "pump," the covered equipment. In particular, the Working Group offered a definition for "pump" along with the related terms “bare pump,” “mechanical equipment,” “driver,” and “controls.” (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendations #1 and 2 at pp. 1–2) Accordingly, in the April 2015 pumps test procedure NOPR, DOE proposed adopting these recommended definitions with slight modification. 80 FR 17586, 17591 (April 1, 2015). Specifically, in the April 2015 pumps test procedure NOPR, DOE proposed the following terms:

- Pump means equipment that is designed to move liquids (which may include entrained gases, free solids, and totally dissolved solids) by physical or mechanical action and includes at least a bare pump and, if included by the manufacturer at the time of sale, mechanical equipment, driver, and controls.
- Bare pump means a pump excluding mechanical equipment, driver, and controls.
- Mechanical equipment means any component of a pump that transfers energy from a driver to the bare pump.
- Driver means 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.
- Control means any device that can be used to operate the driver. Examples include, but are not limited to, continuous or non-continuous controls, schedule-based controls, on/off switches, and float switches.

80 FR 17586, 17591-92 (April 1, 2015).

HI expressed agreement with the proposed definitions, except for the text "entrained gases" in the proposed definition for pump. HI indicated that the text "entrained gasses" should be changed to "dissolved gasses" because pumps within scope are not designed to pump entrained gas, and small amounts of entrained gas would result in a loss of performance and efficiency. (HI, No. 8 at p. 4)

DOE understands that, whereas dissolved gases are in solution and would not appear as bubbles in the pumped liquid, entrained gases are not in solution and would appear as bubbles in the pumped liquid. In addition, DOE agrees that pumps within the scope of this rulemaking are not designed to pump entrained gas. This has been acknowledged through the definition of "clean water pump," as described in section III.A.3 of this final rule, which specifies that the total gas content of the water must not exceed the saturation volume.[13] However, the definition for "pump" applies in general to all pumps, which are covered under EPCA (see 42 U.S.C. 6311(1)(A)), and is broader than the scope of this rulemaking. Changing the language in the definition of "pump" from "dissolved gasses" to "entrained gasses" would suggest that DOE's coverage of pumps was limited. In addition, such a change would limit DOE's coverage to a subset of the pumps intended by the Working Group and proposed in the NOPR. Therefore, DOE declines to make the requested change.

[13] In general, entrained gasses, or gas bubbles, will only form when the total gas content of the water is above the saturation volume of the liquid. Otherwise, gases are more likely to stay dissolved in the liquid and not generate gas bubbles.

DOE did not receive comments on other aspects of the "pump" definition or on the other terms discussed in this section. As such, DOE is adopting definitions for the terms "pump," "bare pump," "mechanical equipment," "driver," and "control" as proposed in the April 2015 pumps test procedure NOPR without further changes.

b. Definition of Categories of Controls

The definition of "control" established in this final rule is broad. DOE acknowledges the definition may include many different kinds of electronic or mechanical devices that can "control the driver" of a pump (e.g., continuous or non-continuous controls, timers, and on/off switches). These various controls may use a variety of mechanisms to control the pump for operational reasons, which may or may not result in reduced energy consumption.

In the April 2015 pumps test procedure NOPR, DOE proposed specific test methods for pumps that are sold with motors that are paired with controls that adjust the speed of the driver, as DOE determined that these were the most common type of controls that reduced energy consumption in the field. Similarly, DOE proposed that such pumps equipped with speed controls could apply the PEI_{VL} metric. 80 FR 17586, 17592-93 (April 1, 2015). Additionally, DOE proposed that pumps sold with motors and controls other than speed controls[14] would be subject to the appropriate bare pump and motor test procedures and rated using PEI_{CL}. Id.

[14] Here and throughout this final rule, DOE uses the term "speed controls" to refer to continuous and non-continuous controls, as defined in section III.A.1.b of this document.

To explicitly establish the kinds of controls that may apply the PEI_{VL} metric under the test procedure, DOE proposed to define the terms "continuous control" and "non-continuous control" (see sections III.B and III.E for further discussion of the PEI_{VL} rating metric and its applicability to pumps with controls, respectively):

- Continuous control means a control that adjusts the speed of the pump driver continuously over the driver operating speed range in response to incremental changes in the required pump flow, head, or power output.[15] As an example, variable speed drives (VSDs), including variable frequency drives and electronically commutated motors (ECMs), meet the definition for continuous controls.
- Non-continuous control means a control that adjusts the speed of a driver to one of a discrete number of non-continuous preset operating speeds, and does not respond to incremental reductions in the required pump flow, head, or power output. As an example, multi-speed motors such as two-speed motors meet the definition for non-continuous controls.

80 FR 17586, 17592-93 (April 1, 2015).

DOE requested comment on the proposed definitions of "continuous control" and "non-continuous control." DOE also requested comment on the likelihood of a pump with continuous or non-continuous controls being distributed in commerce, but never being paired with any sensor or feedback mechanisms that would enable energy savings. In response, HI commented that it agrees with the proposed definitions for continuous

[15] HI-40.6, as incorporated by reference, defines pump power output as "the mechanical power transferred to the liquid as it passes through the pump, also known as pump hydraulic power."

control and non-continuous control, and that it does not have data on pumps with speed controls being distributed in commerce without any sensor or feedback mechanisms. (HI, No. 8 at p. 4)

During the public meeting, Regal Beloit requested a clarification related to DOE's definitions of continuous control and non-continuous control. Specifically, Regal Beloit requested clarification regarding whether pumps sold with multi-pole motors and "single-speed controls, which would be considered multi-speed," would be classified as pumps sold with non-continuous controls. (Regal Beloit, NOPR public meeting transcript, No. 7 at p. 98). With respect to Regal Beloit's use of the term "single-speed controls," DOE believes that Regal Beloit is referring to "multi-speed" permanent split capacitor (PSC) motors, which are PSC motors that are offered with two or more discrete speed options. Depending on the specific model, speeds may be adjusted manually with a switch or automatically with a type of control logic. Similarly, multi-pole motors are induction motors that are offered with two or more discrete speed options. Again, speeds may be adjusted manually with a switch or automatically with a type of control logic.

In this final rule, DOE clarifies that, to the extent multi-pole motors and multi-speed PSC motors control the driver speed discretely (via manual switch or control logic) in response to incremental reductions in the required flow, head, or pump power output, such motors would meet the definition of non-continuous controls and would be tested in accordance with the applicable test procedure for pumps sold with motors and non-continuous controls (see section III.E). DOE also clarifies in this final rule that any control that can achieve the specified load points on the reference system curve (see section III.E.2.c) meets DOE's definition of continuous control, as it can achieve the specific flow rate and head values specified by the reference system curve in the test procedure.

CA IOUs asked during the April 2015 NOPR public meeting whether DOE would consider differentiating between two-speed and multi-speed motors, and stated that if more discrete speeds are available there is more opportunity to match the pump and motor to the load. (CA IOUs, NOPR public meeting transcript, No. 7 at pp. 98–99) DOE believes that in this context, CA IOUs is referring to "multi-speed motors" as motors with more than two discrete speeds.

DOE believes the definition of non-continuous control adequately covers all motors with two or more discrete speeds that are sold with any control mechanism that controls the motor speed discretely (e.g., manual switch or control logic). Furthermore, the test procedure for pumps sold with motors and non-continuous controls, as proposed in the April 2015 pumps test procedure NOPR, contains provisions that will typically allow motors with three or more speeds to achieve a lower (less consumptive) PEI_{VL} rating than motors with only two speeds. This procedure is outlined in detail in section III.E.2.c. Consequently, DOE believes that motors with differing numbers of discrete speed options are already differentiated in the proposed test procedure and has determined that it is not necessary to further differentiate between two-speed and multi-speed motors.

After considering HI's agreement with the proposed definitions and the questions raised by Regal Beloit and CA IOUs, DOE is adopting, in this final rule, the definitions for continuous and non-continuous controls, as proposed in the April 2015 pumps test procedure NOPR.

c. Definition of Basic Model

In the course of regulating consumer products and commercial and industrial equipment, DOE has developed the concept of a "basic model" to determine the specific product or equipment configuration(s) to which the regulations would apply. For the purposes of applying pumps regulations, DOE proposed to define what constitutes a basic model of pump.

In the April 2015 pumps test procedure NOPR, DOE defined a basic model in a manner similar to the definitions used for other commercial and industrial equipment, with the exception of two pump-specific issues. Specifically, DOE proposed to define basic model as it applies to pumps to include all units of a given covered equipment type (or class thereof) manufactured by one manufacturer, having the same primary energy source, and having essentially identical electrical, physical, and functional (or hydraulic) characteristics that affect energy consumption, energy efficiency, water consumption, or water efficiency; except that:

1) variation in the number of stages particular radially split, multi-sage vertical in-line casing diffuser (RSV)[16] and vertical turbine submersible (VTS) pump units are sold with would not result in different basic models; and
2) pump models for which the bare pump differs in impeller diameter, or impeller trim, may be considered a single basic model.

80 FR 17586, 17593 and 17641 (April 1, 2015).

The first modification to the basic model definition applies to variation in the number of stages for multi-stage bare pumps[17], which DOE believes will significantly reduce testing burden and is consistent with DOE's proposed test procedure provision that such pumps be tested with a specific number of stages, as discussed in section III.C.2.c. DOE did not receive any comments on the exception to the general basic model definition that different stage versions of multi-stage pumps would be treated as the same basic model and, as such, is adopting this pump-specific provision as proposed, with minor wording revisions for clarity.

The second modification to the typical basic model definition proposed in the April 2015 pumps test procedure NOPR was that a trimmed impeller, though it may impact efficiency, would not be a basis for requiring different bare pump models to be rated as unique basic models.[18] DOE also proposed to base the certified rating for a

---

[16] The acronym RSV abbreviates "radially split vertical," which is a key characteristic of the radially split, multi-stage vertical in-line casing diffuser equipment category.

[17] The implications of the resulting variation in motor selection for pumps sold with motors or motors and controls is discussed in section III.A.1.d.

[18] The implications of the resulting variation in motor selection for pumps sold with motors or motors and controls is discussed in section III.A.1.d.

given pump basic model on that model's full impeller diameter—specifically, all PEI and PER representations for the members of a basic model would be based upon the full impeller model. 80 FR 17586, 17593-94 (April 1, 2015). This proposal is consistent with the Working Group recommendation that the rating of a given pump basic model should be based on testing at full impeller diameter only and that DOE not require testing at reduced impeller diameters. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #7 at p. 3)

Relevant to this proposed requirement, DOE proposed to define the term "full impeller" as it pertains to the rating of pump models in accordance with the test procedure. Specifically, DOE proposed to define full impeller as the maximum diameter impeller with which the pump is distributed in commerce in the United States or the maximum impeller diameter represented in the manufacturer's literature, whichever is larger. For pumps that may only be sold with a trimmed impeller due to a custom application, DOE proposed to define the full impeller as the maximum diameter impeller with which the pump is distributed in commerce. 80 FR 17586, 17593-94 (April 1, 2015)

Under DOE's proposed definition of "full impeller," manufacturers would also be able to represent a model with a trimmed impeller as less consumptive than one with a full impeller. To do so, they would treat that trimmed impeller model as a different basic model and test a representative number of units at the maximum diameter distributed in commerce of that trimmed basic model listing. In such a case, the impeller trim with which the pump is rated would become the "full impeller diameter." In these cases, manufacturers could elect to (1) group individual pump units with bare pumps that vary only in impeller diameter into a single basic model or (2) establish separate basic models (with unique ratings) for any number of unique impeller trims, provided that the PEI rating associated with any individual model were based on the maximum diameter impeller for that basic model and that basic model is compliant with any energy conservation standards established as part of the parallel pumps energy conservation standards rulemaking. (Docket No. EERE-2011-BT-STD-0031; 80 FR 17586, 17593-94 (April 1, 2015)).

DOE noted that, while manufacturers would be able to group pump models with various impeller trims under one basic model with the same certified PEI rating based on the full impeller diameter, all representations of PEI and PER for any individual model would be (1) based on testing of the model with the full impeller diameter in the basic model and (2) rated using method A.1, "bare pump with default motor efficiency and default motor part load loss curve" (explained further in section III.E), regardless of the actual impeller size used with a given pump. Id.

At the April 2015 NOPR public meeting, interested parties representing HI[19] expressed concern regarding the option to consider pumps with trimmed impellers as separate basic models. Specifically, one HI representative from Patterson Pump Company noted that the premise was contrary to the Working Group's agreement that all

[19] Several interested parties identified themselves as representing HI at the April 2015 NOPR public meeting, including Bob Barbour from TACO, Inc.; HI representatives from Xylem (Mark Handzel and Raul Ruzicka), and Al Huber from Patterson Pump Company.

representations for PEI would be done using full impeller diameter, not trimmed impeller diameter. Another HI representative from Xylem (Mark Handzel) stated that reporting is greatly simplified if only reported for full impeller diameter. (HI, NOPR public meeting transcript, No. 7 at pp. 29, 32). The CA IOUs responded that the Working Group had only agreed to what was going to be required for reporting on a mandatory basis, and that its preference was to maintain the flexibility for manufacturers to voluntarily report the information for pumps with trimmed impellers. (CA IOUs, NOPR public meeting transcript, No. 7 at pp. 34, 36) Furthermore, in its written comments, HI agreed with the proposed definition of the term "basic model," which allows manufacturers the option of rating pumps with trimmed impellers as a single basic model or separate basic models. (HI, No. 8 at p. 4) HI also agreed with DOE's proposed definition of full impeller and the proposal that all pump models be rated in a full impeller configuration only. (HI, No. 8 at p. 5)

In response, DOE reaffirms that only reporting PEI at full impeller diameter will be mandatory. Given that some interested parties stated that they prefer maintaining the option of rating pumps with trimmed impellers as separate basic models, and HI did not indicate concern with this option in the written comments, DOE is maintaining the option to rate pumps with trimmed impellers as separate basic models in this final rule. Furthermore, DOE notes that in the case a manufacturer chooses to rate pumps with trimmed impellers as separate basic models, the full impeller definition is still applicable and all representations regarding the PEI and PER must be based on the "full impeller" diameter for that basic model.

Upon further review of the proposed definition for “full impeller,” DOE has determined that the language within the definition is duplicative, and therefore, potentially confusing. Specifically, in the proposed definition, DOE referred to both distribution in commerce and representations in manufacturer literature. However, DOE notes that 42 USC 4291(16) defines distribution in commerce as meaning “to sell in commerce, to import, to introduce or deliver for introduction into commerce, or to hold for sale or distribution after introduction into commerce.” This definition encompasses making advertising materials such as representations in manufacturer literature. Accordingly, DOE has revised the definition for full impeller diameter as follows:

Full impeller diameter means the maximum diameter impeller with which a given pump basic model is distributed in commerce.

d. Basic Models of Pumps Sold with Motors or Motors and Speed Controls

In the April 2015 pumps test procedure NOPR, DOE noted that, for pumps sold with motors and pumps sold with motors and continuous or non-continuous controls, pump manufacturers may pair a given pump with several different motors that have different performance characteristics. 80 FR 17586, 17594 (April 1, 2015). Under the definition of basic model proposed in the April 2015 pumps test procedure NOPR and discussed in section III.A.1.c, each unique pump and motor pairing represents a unique basic model. However, DOE noted that, consistent with DOE’s practice with other products and equipment, pump manufacturers may elect to group similar individual pump models within the same equipment class into the same basic model to reduce testing burden, provided all representations regarding the energy use of pumps within that basic model are identical and based on the most consumptive unit. See 76 FR 12422, 12423 (March 7, 2011). In addition, consistent with DOE's treatment of variation in the number of stages for multi-stage RSV and VTS pumps and impeller trim, in the April 2015 pump test procedure NOPR, DOE proposed that variation in motor sizing as a result of different impeller trims or different number of stages for multi-stage pumps would not serve as a basis for differentiating basic models. 80 FR 17586, 17593 (April 1, 2015)

In response, HI recommended that DOE clarify the definition of "basic model," stating that "pump manufacturers may pair a given pump with several different motors with different performance characteristics, and can include all combinations under one basic model as long as the representations regarding the energy use is based on the most consumptive unit for each given pole speed, given clean water with a specific gravity of 1.0. . . [A]s variation in impeller trim of the bare pump does not constitute a characteristic that would differentiate basic models, variation in motor sizing as a result of different impeller trims would also not serve as a basis for differentiating basic models." (HI, No. 8 at p. 5)

In general, DOE agrees with HI's interpretation. DOE agrees with HI that pump manufacturers may pair a given pump with several different motors with different performance characteristics, and can include all combinations under one basic model if the certification of energy use and all representations made by the manufacturer, are based on the most consumptive bare pump/motor combination for each basic model and are determined in accordance with the DOE test procedure and applicable sampling plans. Furthermore, because variation in impeller trim of the bare pump is not a basis for requiring models to be rated as unique basic models, DOE agrees that variation in the horsepower rating of the paired motor as a result of different impeller trims within a basic model would also not necessarily be a basis for requiring units to be rated as unique basic models. Similarly since RSV and VTS pumps may be sold with varying numbers of stages, the horsepower rating of the paired motor may also vary correspondingly. DOE notes that this variation in motor horsepower does not necessarily constitute a characteristic that will define separate basic models.

However, variation in motor sizing (i.e., horsepower rating) may also be associated with variation in motor efficiency, which is a performance characteristic; typically larger motors are more efficient than smaller motors. For this reason, in response to HI, DOE clarifies that in order to group pumps sold with motors (or motors and controls) into a single basic model (in contrast to grouping bare pumps with variations in impeller trim into a single basic model, as discussed in the previous section), each motor offered in a pump included in that basic model must have motor efficiency rated at the Federal minimum (see the appropriate table for NEMA Design B motors at 10 CFR 431.25)[20] or the same number of bands above the Federal minimum for each respective motor horsepower (see Table 3 of Appendix A to Subpart Y of Part 431).)[21] For example, the Federal minimum for a NEMA Design B 5 HP, 2-pole, enclosed motor

[20] For submersible motors, refer to the default motor efficiency values in this test procedure, shown in Table 2 of Appendix A to Subpart Y of Part 431, with further discussion in section III.D.1.b.
[21] See section III.D.1.b for further discussion of Table 3.

in 10 CFR 431.25 is 88.5. A manufacturer is rating the pump and motor combination with a 90.2 percent efficient motor. In Table 3 of Appendix A to Subpart Y of Part 431, 90.2 is two bands above 88.5. Therefore, for a NEMA Design B 3 HP, 2-pole enclosed motor, in order to be considered as the same basic model, the manufacturer cannot distribute it with a motor with an efficiency less than 88.5 percent, which in Table 3 is two bands above the Federal minimum. If the manufacturer wishes to rate it with a less efficient motor, it must be rated as a separate basic model. This approach will ensure that the PEI and PER representations for the entire basic model will be representative of the performance across various impeller trims and motor horsepower. DOE has added this clarification to the definition of basic model.

DOE did not receive any other comments from interested parties regarding basic models for pumps sold with motors or motors and speed controls.

2. Equipment Categories

In the April 2015 pumps test procedure NOPR, DOE proposed that the test procedure be applicable to the following pump equipment categories: end suction close-coupled (ESCC), end suction frame mounted (ESFM), in-line (IL), RSV, and VTS pumps. 80 FR 17586, 17594-95 (April 1, 2015). DOE also proposed that the test procedure would not be applicable to certain categories of pumps, including circulators, dedicated purpose pool pumps, axial/mixed flow pumps, and positive displacement pumps. Id. at 17597. These proposals were based on the recommendation of the Working Group. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #4, 5A, 5B, and 6 at p. 2) DOE also noted that, while intended to be consistent with this test procedure, the scope of any energy conservation standards proposed for pumps would be discussed as part of a separate rulemaking. Id.

DOE requested comment on the proposed applicability of the test procedure to the five pump equipment categories noted above, namely ESCC, ESFM, IL, RSV, and VTS pumps. HI commented that it agrees that the proposed test procedure was applicable to the five pump equipment categories noted. (HI, No. 8 at p. 5) HI also agreed that circulators and pool pumps should be handled under two separate rulemakings. (HI, No. 8 at p. 7) No other interested parties provided comments on the scope of applicability of the proposed test procedure. As the amendments DOE is making to the proposed test procedure provisions do not significantly change the test methods or approach specified in the pump test procedure, and receiving no dissenting comments, DOE adopts its proposal that the test procedure provisions established in this final rule are applicable to the same scope of pumps discussed in the April 2015 pumps test procedure NOPR. 80 FR 17586, 17591-17601 (April 1, 2015).

The specific definitions and specifications DOE proposed to establish the scope of the test procedure, and any comments DOE received on those definitions, are discussed in the subsequent sections III.A.2.a, III.A.2.b, III.A.2.c, and III.A.2.d. The final equipment category definitions DOE is adopting in this final rule are presented in section III.A.2.e.

a. Definitions of Pump Equipment Categories

As noted, in the April 2015 pumps test procedure NOPR, DOE proposed specific definitions for the five categories of pumps (i.e., ESCC, ESFM, IL, RSV, and VTS) to establish the pumps to which the proposed test procedure is applicable. 80 FR 17586, 17595-96 and 17641-42 (April 1, 2015). To assist in defining these five pump categories, DOE also proposed the following definitions for several specific characteristics of the five pumps categories for which the test procedure is applicable—namely rotodynamic pump, single-axis flow pump, and end suction pump:

- Rotodynamic pump means a pump in which energy is continuously imparted to the pumped fluid by means of a rotating impeller, propeller, or rotor.
- Single axis flow pump means a pump in which the liquid inlet of the bare pump is on the same axis as the liquid discharge of the bare pump.
- End suction pump means a rotodynamic pump that is single-stage and in which the liquid enters the bare pump in a direction parallel to the impeller shaft and on the end opposite the bare pump's driver-end.

Id.

Based on these three definitions involving general pump characteristics, DOE proposed to define the following five pump equipment categories to which the test procedure applies as follows:

1) End suction frame mounted (ESFM) pump means an end suction pump wherein:

a) the bare pump has its own impeller shaft and bearings and so does not rely on the motor shaft to serve as the impeller shaft;

b) the pump requires attachment to a rigid foundation to function as designed and cannot function as designed when supported only by the supply and discharge piping to which it is connected; and

c) the pump does not include a basket strainer.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH0 and OH1, as described in ANSI/HI 1.1-1.2–2014.

2) End suction close-coupled (ESCC) pump means an end suction pump in which:

a) the motor shaft also serves as the impeller shaft for the bare pump;

b) the pump requires attachment to a rigid foundation to function as designed and cannot function as designed when supported only by the supply and discharge piping to which it is connected; and

c) the pump does not include a basket strainer.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH7, as described in ANSI/HI 1.1-1.2–2014.

3) In-line (IL) pump means a single-stage, single axis flow, rotodynamic pump in which:

a) liquid is discharged through a volute in a plane perpendicular to the impeller shaft; and

b) the pump requires attachment to a rigid foundation to function as designed and cannot function as designed when supported only by the supply and discharge piping to which it is connected.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH3, OH4, or OH5, as described in ANSI/HI 1.1-1.2–2014.

4) <u>Radially split, multi-stage, vertical, in-line, diffuser casing (RSV) pump</u> means a vertically suspended, multi-stage, single axis flow, rotodynamic pump in which:

a) liquid is discharged in a plane perpendicular to the impeller shaft;

b) each stage (or bowl) consists of an impeller and diffuser; and.

c) no external part of such a pump is designed to be submerged in the pumped liquid.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature VS8, as described in the ANSI/HI 2.1-2.2–2008).

5) <u>Vertical turbine submersible (VTS) pump</u> means a single-stage or multi-stage rotodynamic pump that is designed to be operated with the motor and stage(s) (or bowl(s)) fully submerged in the pumped liquid, and in which:

a) each stage of this pump consists of an impeller and diffuser and

b) liquid enters and exits each stage of the bare pump in a direction parallel to the impeller shaft.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature VS0, as described in ANSI/HI 2.1-2.2–2008.

<u>Id.</u>

In the April 2015 pumps test procedure NOPR, DOE requested comment on the proposed equipment category definitions and related terminology. Comments DOE received on these definitions and DOE's responses to those comments are discussed in the following subsections. DOE notes that comments regarding the exclusion of circulators and dedicated-purpose pool pumps, which are addressed in sections III.A.2.b and III.A.2.c of this final rule, are also pertinent to the definitions of the ESCC, ESFM, IL, RSV, and VTS equipment categories and are also discussed in this section.

HI Nomenclature

DOE noted that any references to HI nomenclature in ANSI/HI 1.1-1.2–2014 or ANSI/HI 2.1-2.2–2008 were incorporated into the definitions of the aforementioned pump equipment categories as examples only and clarified that, in cases where there is a conflict between the description provided in ANSI/HI 1.1-1.2–2014 or ANSI/HI 2.1-2.2–2008, as applicable, and DOE's definitions established at 10 CFR 431.462, the language in the regulatory text would prevail. Id.

DOE requested comment on whether the references to ANSI/HI nomenclature are necessary as part of the equipment definitions in the regulatory text; whether such references would be likely to cause confusion due to inconsistencies; and whether discussing the ANSI/HI nomenclature in this preamble would provide sufficient reference material for manufacturers when determining the appropriate equipment category for their pump models. At the April 2015 NOPR public meeting, an HI representative from Xylem (Mark Handzel) advocated the use of ANSI/HI nomenclature without new DOE nomenclature. (HI, NOPR public meeting transcript, No. 7 at p. 63) In written comments, HI indicated that it affirms the importance of any pump rulemaking using ANSI/HI designations and nomenclature, citing common usage by U.S. pump manufacturers, distributors, engineering consulting firms, and pump users. (HI, No. 8 at p. 6) HI also commented that all references to ANSI/HI 2.1-2.2–2008 should be changed to ANSI/HI 2.1-2.2–2014 because the latter is the current version. (HI, No. 8 at p. 13) The EEAs commented that they support the proposed definitions for the pump types to which the proposed test procedures would be applicable; they also indicated that they believe this approach would both limit the risk that a manufacturer could make a small change to a pump design in order to avoid having to meet the pump efficiency standards and help to provide clarity to manufacturers. (EEAs, No. 10 at p. 1)

After reviewing the comments, DOE is maintaining its definitions for the pump equipment categories presented in the April 2015 pumps test procedure NOPR, which references the ANSI/HI nomenclature as illustrative only. DOE believes that this approach strikes the best balance between the needs of the industry and the ability of DOE to enforce its regulations for pumps appropriately. DOE reiterates that the scope of the rulemaking is not limited to pumps meeting the ANSI/HI nomenclature referenced in the definitions and that any pump model meeting one of the DOE equipment category definitions is considered to be part of that equipment category, whether or not the pump is considered by the industry to be part of one of the referenced ANSI/HI nomenclature subgroups or a different subgroup.

Further, in preparing this final rule, DOE reviewed the ANSI/HI nomenclature to ensure that all applicable categories of pumps that would meet DOE's proposed equipment definitions were listed. Upon review, DOE noticed that the styles of pumps identified as OH2, OH3A, OH5A, and OH6 in ANSI/HI 1.1-1.2–2014 may be considered by some parties to meet ESCC, ESFM, or IL pump definitions because they share some similar characteristics with those categories of pumps. DOE wishes to clarify that the styles of pumps generally considered to be OH2, OH3A, OH5A, and OH6 are covered equipment in that they meet the definition of "pump," but are not subject to the test procedure established in this final rule, since they do not fall within the specific scope of pumps to which the test procedure is applicable. Specifically, DOE determined that OH3A and OH5A are not within the scope of this rule because they do not meet the definition of end-suction pump (i.e., liquid does not enter pump in a direction parallel to the impeller shaft due to inlet adapter) and do not meet the definition of IL pump (i.e., the flow inlet and outlet are on the same plane but not on the same axis). In addition, DOE believes that the majority of these OH3A and OH5A pumps are non-clogging and thus would also be excluded because they do not meet DOE's definition of clean water pump, as discussed further in section III.A.3.

Regarding OH6 pumps, DOE notes that such pumps include a high speed integral gear such that the impeller shaft will rotate faster than the driver. While these pumps meet the definition of IL pumps, they are excluded from the scope of pumps subject to this test procedure because they operate at impeller speeds greater than the nominal speed limitations discussed in section III.A.4 and III.C.2.c. In addition, the impellers and drivers of OH6 pumps rotate at different speeds and, thus, would be excluded based on DOE's revised specifications regarding the impeller and driver rotating speeds of pumps addressed by this test procedure (see section III.A.4). Similarly, DOE notes that OH2 pumps would meet the definition of an ESFM pump, but would be excluded because such pumps are designed specifically for pumping hydrocarbon fluids, as noted by the American Petroleum Institute Standard 610 certification and, as such, are not clean water pumps. For these reasons, DOE is not referencing OH2, OH3A, OH5A, or OH6 nomenclature in the definitions of ESCC, ESFM, IL, RSV, and VTS established in this rulemaking.

Finally, DOE notes that in April 2014, HI released an updated version of ANSI/HI 2.1-2.2, ANSI/HI 2.1-2.2–2014. DOE reviewed ANSI/HI 2.1-2.2–2014 and found the documents to be substantially the same as ANSI/HI 2.1-2.2−2008, with the exception of the addition of a new definition and description for pipe length, more detailed characteristics identified on some of the figures, and slight reorganization of the sections to improve document flow. DOE notes that none of these minor changes affect the content pertinent to the references to ANSI/HI 2.1-2.2–2008nomenclature proposed in the April 2015 pumps test procedure NOPR. As such, DOE believes that it is appropriate to reference the most up-to-date industry standard and is updating all references in the RSV and VTS equipment category definitions from ANSI/HI 2.1-2.2–2008 to ANSI/HI 2.1-2.2–2014 in this final rule.

Specific Styles of IL Pumps

In response to DOE's request for comment on all proposed pump definitions in general, HI commented that twin head pumps, which combine two impeller assemblies into a common single axis flow casing with a single inlet and discharge, were not included in DOE's definitions and should be added to the rulemaking scope. (HI, No. 8 at p. 3) DOE notes that such pumps are a style of IL pump and, thus subject to the test procedure and standards as an IL pump, but DOE understands that this inclusion was not explicitly laid out in the NOPR. As such, twin head pumps meet the definition of IL pumps as proposed in the April 2015 pumps test procedure NOPR. Specifically, twin head pumps are single-axis flow, rotodynamic pumps with single-stage impellers and in which liquid is discharged through a volute in a plane perpendicular to the impeller shaft. However, to clarify the applicability of the IL pump definition and DOE's pump test procedure to twin head pumps, DOE is adopting in this final rule a definition of twin head pump as follows:

Twin head pump means a dry rotor, single-axis flow, rotodynamic pump that contains two impeller assemblies, which share a common casing, inlet, and discharge, and each of which (a) contains an impeller, impeller shaft (or motor shaft in the case of close-coupled pumps), shaft seal or packing, driver (if present), and mechanical equipment (if present); (b) has a shaft input power that is greater than or equal to one horsepower and less than or equal to two hundred horsepower at best efficiency point (BEP) and full impeller diameter; (c) has the same primary energy source (if sold with a driver) and the same electrical, physical, and functional characteristics that affect energy consumption or energy efficiency; (d) is mounted in its own volute; and (e) discharges liquid through its volute and the common discharge in a plane perpendicular to the impeller shaft.

In this final rule, DOE is also clarifying the testing and certification requirements for such pumps. For the purposes of applying the DOE test procedure to and certifying twin head pumps, DOE is clarifying that such pumps should be tested configured with a single impeller assembly, as discussed further in section III.C.2.c.

RSV Pump Definition

DOE also requested specific comment on whether it needed to clarify the flow direction to distinguish RSV pumps from other similar pumps when determining test procedure and standards applicability and on whether any additional language would be necessary in the proposed RSV definition in the April 2015 pumps test procedure NOPR to make the exclusion of immersible pumps clearer. HI commented that it believes the icons shown and the definition found in ANSI/HI 2.1-2.2–2014 provide sufficient clarity to the flow direction, and that it does not believe any additional language is necessary. (HI, No. 8 at pp. 6–7) DOE reviewed the figures in ANSI/HI 2.1-2.2–2014 and believes that the figure is illustrative of the general equipment characteristics for RSV pumps. The description accompanying the figure also describes the manner in which liquid enters and exits the pump. Specifically, section 2.1.3.6 of ANSI/HI 2.1-2.2–2014 states that, for RSV pumps, "fluid enters one nozzle of the in-line casing and is directed to the inlet of an internal multi-stage diffuser pump. After traveling through multiple stages, the liquid exits at the top stage of the pump where the flow is redirected via the outer sleeve to the opposing nozzle of the in-line casing." As DOE's definition of RSV pump references the figures and description in ANSI/HI 2.1-2.2–2014, and this description of flow path through the pump is not inconsistent or conflicting with DOE's definition of RSV pump, DOE does not believe that further clarification is necessary in this regard.

Regarding the exclusion of immersible pumps, HI commented that it did not believe any additional clarification was necessary. (HI, No. 8 at pp. 6–7) Therefore, in this final rule, DOE has determined that the adopted language is sufficient to exclude any immersible pumps from treatment as an RSV pump for purposes of DOE's regulations.

VTS Equipment Terminology

Upon review of CIP Working Group transcripts and slides, DOE also determined that interested parties had requested the equipment category "vertical turbine submersible" be termed "submersible turbine," given that some of these pumps are installed horizontally. (CIP Working Group transcript, No. 14 at p. 263) DOE notes that the definition proposed for vertical turbine submersible is silent as to installation orientation and, as a result, would include horizontally installed pumps. DOE believes that referring to submersible turbine pumps as "vertical turbine submersible," when horizontally mounted submersible turbine pumps are also included in the equipment category, as defined, could lead to confusion among manufacturers and in the market place. As such, and given that changing the defined term from vertical turbine submersible to submersible turbine would not change the scope of the definition, DOE is revising the nomenclature in this final rule to match that used in the CIP Working Group, which more accurately describes the subject equipment. In the preamble to this final rule, DOE has retained the VTS abbreviation for the submersible turbine equipment category for consistency with the April 2015 pump test procedure NOPR, pumps energy conservation standards rulemaking (Docket No. EERE-2011-BT-STD-0031), and all Working Group discussions and recommendations to date (Docket No. EERE-2013-BT-NOC-0039). However, DOE is adopting the acronym "ST" for the regulatory text for long-term consistency with the defined term.

ESFM Equipment Terminology

Similarly, the "end suction frame mounted" category proposed in the NOPR had been referred to as "end suction frame mounted/own bearings" in the CIP Working Group documentation. (See for example, EERE-2013-BT-NOC-0039-0092 at p. 2 and EERE-2013-BT-NOC-0039-0031 at p. 4) The proposed end suction frame mounted definition would be inclusive of own bearings pumps, or any end-suction pump that "does not rely on the motor shaft to serve as the impeller shaft." 80 FR 17586, 17641 (April 1, 2015). DOE intended the ESFM and ESCC equipment category definitions proposed in the April 2015 pumps test procedure NOPR to be mutually exclusive, whereby pumps that are close coupled to the motor and share a single impeller and motor shaft would be part of the ESCC equipment category, and all other end suction pumps that are mechanically-coupled to the motor and for which the bare pump and motor have separate shafts would be part of the ESFM equipment category.

DOE understands that there are several coupling and mounting methods for pairing a bare pump and motor, in addition to frame mounting, and that referring to the ESFM equipment category based only on that criteria may be misleading. To clarify the applicability of the previously defined end suction frame mounted equipment category to own bearing pumps, and given that changing the term itself would not change the scope of the definition, DOE is revising the nomenclature in this final rule to match that used in the CIP Working Group. Therefore, in this final rule, DOE is defining this equipment category as end-suction frame mounted/own bearing and adding to the definition the term "mechanically-coupled" to clarify that the ESFM equipment is, in fact, inclusive of many coupling methods. DOE is further adopting a specific definition for "mechanically-coupled," as mutually exclusive with "close-coupled," to explicitly establish the coupling methods to which the ESFM equipment category applies. The definition of mechanically-coupled consists of text that was in the proposed definition for ESFM and does not change the scope of ESFM from the proposal.

b. Circulators

Circulators, which are a specific kind of rotodynamic pump, are small, low-head pumps similar to the IL configuration pumps that are generally used to circulate water in hydronic space conditioning or potable water systems in buildings.

The CIP Working Group recommended that circulators be addressed as part of a separate rulemaking process that would involve informal negotiation between interested parties followed by an ASRAC-approved negotiation. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #5A at p. 2)

In the April 2015 test procedure NOPR, DOE also proposed to exclude circulators from the rulemaking, and proposed a definition that would be mutually exclusive from the other pumps in the rulemaking. Specifically, DOE proposed definitions for circulators, ESCC, ESFM, and IL pumps that were mutually exclusive, based on the assumption that circulators require only the support of the supply and discharge piping to function as designed, whereas ESCC, ESFM, and IL pumps require attachment to a rigid foundation to function as designed. In response to the proposed circulator definition, DOE received comments from several interested parties, addressed below. However, DOE has not yet received any formal proposals or requests for negotiation from the interested parties.

The EEAs and CA IOUs expressed concern that the portion of the proposed circulator definition that describes circulators as "requir[ing] only the support of the supply and discharge piping to which it is connected to function as designed," may lead to the design of circulators with alternative mounting intended to circumvent regulation. (EEAs, No. 10 at p. 1; CA IOUs, No. 13 at pp. 4–5) HI agreed that no pump definition should be associated with a rigid foundation, as in the industry rigid foundation has a different connotation than DOE is using. (HI, No. 8 at pp. 5-6, 10). HI also disagreed with the proposed circulator definition, commenting that there are many end suction and close-coupled IL pumps that would meet the proposed circulator definition but that are not considered circulators. Instead, HI stated its belief that such pumps should be included in the scope of pumps considered in this rulemaking. As a result, HI recommended revising the definitions of circulator, ESFM, ESCC, and IL pumps, as well as other related definitions. (HI, No. 8 at pp. 7–8) Following the close of the comment period, the HI circulator pump committee resubmitted revised definitions for circulator and IL pumps, and other related definitions. (HI, No. 15 at pp. 1−3)

DOE reviewed both sets of HI's recommended definitions and found them to be essentially the same. Specifically, HI's circulator pump committee offered the following revised definitions of IL pumps and circulator pumps, which were also included in HI's comments submitted in response to the April 2015 pumps test procedure NOPR:

"In-line pump means a single-stage, single-axis flow, dry rotor, rotodynamic pump that has a shaft input power greater than or equal to one horsepower and less than or equal to two hundred horsepower at BEP and full impeller diameter, in which liquid is discharged through a volute in a plane perpendicular to the shaft, except for: those that are short-coupled or close-coupled, have a maximum hydraulic power that is less than or equal to five horsepower at the full impeller diameter and over the full range of operation, and are distributed in commerce with a horizontal motor. Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH3, OH4, or OH5, as described in ANSI/HI 1.1-1.2–2014, within the specified horsepower range. Pumps complying with ANSI/HI nomenclature CP1, CP2, and CP3, as described in ANSI/HI 1.1-1.2–2014, would not meet the definition of in-line pump." (HI, No. 8 at pp. 5-6; HI, No. 15 at p. 1)

"Circulator pump means a single stage, in-line, rotodynamic pump that meets one of the following descriptions:

i. [Wet Rotor Circulator] A single-axis flow, close-coupled, wet rotor pump that: (1) has a maximum hydraulic power greater than or equal to 1/40 hp and less than or equal to 5 hp at full impeller diameter and over the full range of operation, (2) is distributed in commerce with a horizontal motor, and (3) discharges the pumped liquid through a volute in a plane perpendicular to the shaft. Examples include, but are not limited to, pumps complying with ANSI/HI 1.1-1.2–2014 nomenclature CP1; or

ii. [Dry Rotor Two-Piece Circulator] A single-axis flow, close-coupled, dry rotor pump that: (1) has a maximum hydraulic power greater than or equal to 1/40 hp and less than or equal to 5 hp at full impeller diameter and over the full range of operation, (2) is distributed in commerce with a horizontal motor, and (3) discharges the pumped liquid through a volute in a plane perpendicular to the shaft. Examples include, but are not limited to, pumps complying with ANSI/HI 1.1-1.2–2014 nomenclature CP2; or

iii. [Dry Rotor Three-Piece Circulator] A single-axis flow, short-coupled, dry rotor pump, either flexibly or rigidly coupled that: (1) has a maximum hydraulic power greater than or equal to 1/40 hp and less than or equal to 5 hp at full impeller diameter and over the full range of operation, (2) is distributed in commerce with a horizontal motor, and (3) discharges the pumped liquid through a volute in a place perpendicular to the shaft. Examples include, but are not limited to, pumps complying with ANSI/HI 1.1-1.2–2014 nomenclature CP3."

(HI, No. 8 at pp. 8–9; HI, No. 15 at p. 1)

HI also recommended several supporting definitions, including definitions for single-axis flow pump, close-coupled pump, short-coupled pump, rigid-coupled pump, flexibly-coupled pump, hydraulic power, wet rotor pump, dry rotor pump, horizontal motor, and non-horizontal motor. (HI, No. 8 at pp. 9–10; HI, No. 15 at pp. 2−3)

The EEAs and CA IOUs also stated that they are collectively discussing an improved definition of circulators with HI. (EEAs, No. 10 at p. 1; CA IOUs, No. 13 at pp. 4–5).

In light of the continued discussions among these interested parties regarding future definitions, test procedures, and energy conservation standards for circulators, DOE has decided to refrain from defining the term "circulator" in this rulemaking. Rather than explicitly define the term circulator in this rule, DOE has modified the definitions of ESCC, ESFM, IL, VTS, and RSV to specifically exclude certain categories of pumps that are widely considered circulators by the industry, using many of the criteria and characteristics of circulators indicated by HI in its comments and proposed in the April 2015 pumps test procedure NOPR.

In particular, in its definition of IL pump, DOE excluded pumps that are commonly marketed and sold as circulators in the pump industry by utilizing the design features of a horizontal motor, as well as a hydraulic power less than or equal to 5 hp. This is consistent with HI's suggested definition of IL pump as well as circulator pump, which includes reference to a horizontal motor and a horsepower range of 1/40 to 5 hydraulic hp. DOE agrees that a horizontal motor, which is a motor that is required to be oriented with the motor shaft in a horizontal position in order to operate as designed, is a distinguishing feature of a circulator. To clearly establish this characteristic, DOE is also defining the term horizontal motor in this rulemaking based on the definition HI suggested in its comments. Specifically, HI's proposed definition and the definition DOE is adopting in this final rule are as follows:

Horizontal motor means a motor that requires the motor shaft to be in a horizontal position to function as designed, as specified in the manufacturer literature.

DOE notes that it is maintaining a lower shaft limit of 1 hp for the IL pump equipment category and only specifically excluding those pumps that have both: (1) a hydraulic output of less than 5 hp and (2) a horizontal motor. As such, any IL pumps that have a shaft horsepower greater than or equal to 1 hp and hydraulic output less than 5 hp and are not sold with a horizontal motor, as well as IL pumps that have a hydraulic output greater than or equal to 5 hp and shaft horsepower less than or equal to 200 hp and are sold with a horizontal or non-horizontal motor, would continue to be included in the IL pump definition and subject to the test procedure established in this final rule. DOE notes that the majority of pumps that are commonly referred to as circulators have a shaft input power less than 1 hp. Such pumps may operate with or without horizontal motors. As such, the lower shaft power limit in the IL pump definition excludes these pumps from the scope of this rulemaking.

DOE also acknowledges that HI recommended establishing the hydraulic horsepower threshold over the full range of operation of the pump. (HI, No. 8 at pp. 5−6 and 8−9; HI, No. 15 at p. 1) However, DOE notes that the other horsepower thresholds referenced in this final rule reference pump shaft input power as measured at BEP. DOE also notes that the test procedure established in this final rule contains a specific and repeatable methodology for determining BEP of a tested pump. Conversely, in the proposed test procedure, DOE did not define the "full range of operation" of a pump or propose a method for how to determine it. Since it is important that DOE's test procedures be as precise and unambiguous as possible, DOE believes that it is important that the hydraulic horsepower of a pump be determined in a consistent manner when determining whether or not the pump meets the definition of an IL pump and, thus, is subject to DOE's pumps test procedure establish in this final rule. Therefore, in this final rule, DOE is establishing the hydraulic horsepower threshold for circulator pumps as determined at BEP. That is, DOE will exclude from the definition of IL pump, IL pumps with a hydraulic horsepower less than 5 hp, as determined at full impeller diameter and BEP, and that are distributed in commerce with a horizontal motor, as those pumps are considered to be circulator pumps.

Consistent with the changes to the IL definition, DOE is also incorporating horsepower limits into the ESCC, ESFM, RSV, and VTS equipment category definitions. DOE notes that, in the April 2015 pumps test procedure NOPR, DOE proposed to establish the scope of the test procedure using a horsepower range of greater than or equal to 1 hp and less than 200 hp that was applicable to all ESCC, ESFM, IL, RSV, and

VTS pumps. 80 FR 17586, 17600 (April 1, 2015). However, to maintain consistent format among the five defined equipment categories, DOE is including this established horsepower range in each of the equipment category definitions explicitly rather than in a separate scope limitation. DOE discusses the horsepower range and other parameters used to establish the scope of the test procedure in section III.A.4.

Additionally, DOE has added the design feature of a "dry rotor" to the definition of an IL pump[22] and added a definition of dry rotor pump, as suggested by HI. This feature excludes pumps that comply with ANSI/HI nomenclature CP1, also referred to as wet rotor circulators, as described in ANSI/HI 1.1-1.2–2014. This definition is also consistent with HI's proposed IL and circulator pump definitions. DOE notes that wet rotor pumps were proposed to be excluded from the scope of the test procedure in the April 2015 pumps test procedure NOPR under the definition of "sealless pump." Specifically, DOE proposed a definition of sealless pump to include both: (1) a pump that transmits torque from the motor to the bare pump using a magnetic coupling and (2) a pump in which the motor shaft also serves as the impeller shaft for the bare pump and the motor rotor is immersed in the pumped fluid. 80 FR at 17641-42. HI's proposed definition of wet rotor is identical to the second clause of DOE's proposed sealless pump definition. As such, in this final rule, DOE defines dry rotor pump, consistent with the definition proposed by HI, and to incorporate the term dry rotor into the ESFM, ESCC, IL, RSV, and VTS equipment category definitions. Given the mutually exclusive

[22] In the NOPR, DOE had excluded sealless pumps, including wet rotor pumps, from the scope of the rulemaking in addition to explicitly limiting the defined pump categories to dry rotor pumps. 80 FR 17586, 17598-99 (April 1, 2015) See section III.A.3.b.

relationship between wet and dry rotor pumps, the definitions of ESCC, ESFM, IL, RSV, and VTS pumps, as established in section III.A.2.a, now implicitly exclude wet rotor pumps from the scope of this test procedure. This implicit exclusion of wet rotor pumps alleviates the need to explicitly exclude wet rotor pumps using the definition of sealless pump as proposed in the NOPR. Further discussion of modifications to the definition of sealless pump are found in section III.A.2.b.

DOE also acknowledges the concern from interested parties regarding the potential issues associated with referencing attachment to a rigid foundation. As noted in the NOPR, DOE initially proposed such a design feature to clearly differentiate and exclude circulators from other, similar categories of pumps that would be subject to the proposed test procedure. However, DOE has, based on comments received from interested parties, revised its approach to the exclusion of circulators and, consequently, this design feature is no longer needed in the definitions of IL, ESCC, and ESFM. Instead, DOE has made other modifications to the applicable definitions to continue to exclude circulators from the equipment categories addressed in this rulemaking, as discussed above.

In addition to the parameters necessary to exclude circulators from the scope of pumps for which the test procedure is applicable, the CA IOUs commented that certain multi-stage pumps should be included in the definition of a circulator, as proposed by DOE. CA IOUs also provided an example of a commercially available style of pump that they believe to be a multi-stage circulator. (CA IOUs, No. 13 at pp. 4–5) DOE reviewed the example style of pump provided by the CA IOUs and found that this specific style of pump is available in sizes from 0.5 to 75 motor hp, depending on impeller diameter and number of stages. DOE also concluded that specific models within this general pump family, namely those with shaft horsepower greater than or equal to 1 hp, meet the definition of an RSV pump and therefore are included in the scope of this rulemaking. Conversely, other models within the same pump family with shaft horsepower less than 1 hp do not meet the definition of an RSV pump and are not subject to the test procedure established in this rulemaking. Consequently, given that DOE has withdrawn its proposal to define circulators at this time, DOE has determined that it does not need to define or address these small RSV pumps in this rulemaking.

c. Pool Pumps

The CIP Working Group formally recommended that DOE initiate a separate rulemaking for dedicated-purpose pool pumps (DPPPs) by December 2014. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #5A at p. 2) In the April 2015 pumps test procedure NOPR, DOE proposed defining a “dedicated-purpose pool pump” as an end suction pump designed specifically to circulate water in a pool and that includes an integrated basket strainer. 80 FR 17586, 17641 (April 1, 2015). DOE developed this proposed definition to help distinguish a DPPP from other categories of pumps under consideration in this rulemaking (Docket No. EERE-2013-BT-TP-0055).

In response, APSP requested that DOE continue to keep pool pumps separate from the scope of pumps considered in this rulemaking (APSP, No. 12 at p.1), and the CA IOUs encouraged ASRAC to establish a new working group for DPPP. (CA IOUs, No. 13 at pp. 1-2) In July 2015, DOE issued a RFI on DPPPs requesting data and information from interested parties on this equipment (July 2015 DPPP RFI). 80 FR 38032 (July 3, 2015). On August 25, 2015, DOE also published a notice of intent to establish a working group for DPPPs. 80 FR 51483. See https://www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/14 for more updates and information on the DPPP rulemaking.

DOE also received several comments regarding its proposed definition. During the April 2015 NOPR public meeting, CA IOUs expressed that the defining characteristic of a pool pump may not be the strainer basket, as not all pool pumps have them. (CA IOUs, NOPR public meeting transcript, No. 7 at pp. 57-58, 68) An HI representative from Xylem (Mark Handzel) responded that commercial pool pumps without basket strainers would be considered under one of the equipment categories addressed in this rulemaking. (HI, NOPR public meeting transcript, No. 7 at pp. 58–59) An HI representative from Xylem (Paul Ruzicka) also suggested that, on the residential side, pool pumps are double insulated products. (HI, NOPR public meeting transcript, No. 7 at pp. 69–70)

In written comments, the EEAs and the CA IOUs noted that many pool pumps, including booster pumps, do not include an integrated basket strainer, and that not all pool pumps are designed specifically to circulate water (EEAs, No. 10 at p. 2; CA IOUs, No. 13 at p. 2–3). The CA IOUs noted that 40 percent of California residential in-ground pools have booster pumps that are operated 2.5 hours per day. The size is typically ¾ nameplate horsepower with a service factor of 1.5. The CA IOUs recommended that these be considered pool pumps and excluded from this rulemaking, further noting that these manufacturers were not involved in the CIP Working Group deliberations. The CA IOUs also stated that mass market commodity pool pumps are unique because either the pump is secured directly to the motor; or the pump and motor are each factory secured to a common frame. (CA IOUs, No. 13 at pp. 2–4)

In separate written comments, APSP and the CA IOUs recommended the following definition:

"A 'pool pump' is a pump with the following characteristics:

- An integral end suction pump and motor combination specifically designed for pool and spa applications.
- The impeller is attached to a motor (or motor and controller) served by single-phase power five total horsepower or less.
- The pump is secured directly to the motor, or the pump and motor are factory secured to a common frame." (APSP, No. 12 at p. 1; CA IOUs, No. 13 at p. 3–4)

DOE's original intent in proposing a definition for DPPP in the April 2015 pumps test procedure NOPR was to properly exclude them from this rulemaking. Upon review, DOE agrees with certain of the submitted comments on the proposed definition, such as that all pumps associated with pools may not include an integrated basket strainer. For example, DOE is aware that booster pumps are not typically sold with integrated basket strainers and some filter pumps may be sold separately from the strainer, as discussed in the July 2015 DPPP RFI. 80 FR 26475, 26481 (May 8, 2015).

Therefore, after reviewing the comments submitted by interested parties, DOE has decided to refrain from adopting a definition for DPPP in this final rule. Instead, in this final rule, DOE is excluding DPPP from the definitions for ESCC and ESFM pumps, and DOE will define DPPP in the separate DPPP rulemaking that was initiated with the RFI.

d. Axial/Mixed Flow and Positive Displacement Pumps

"Axial/mixed flow pump" is a term used by the pump industry to describe a rotodynamic pump that is used to move large volumes of liquid at high flow rates and low heads. These pumps are typically custom-designed and used in applications such as dewatering, flood control, and storm water management.

Positive displacement (PD) pumps are a style of pump that operates by first opening an increasing volume to suction; this volume is then filled, closed, moved to discharge, and displaced. PD pumps operate at near-constant flow over their range of operational pressures and can often produce higher pressure than a centrifugal pump, at a given flow rate. PD pumps also excel at maintaining flow and efficiency for liquids more viscous than water. When used in clean water applications, PD pumps are typically chosen for high pressure, constant flow applications such as high pressure power washing, oil field water injection, and low-flow metering processes.

The CIP Working Group recommended excluding both of these types of pumps from prospective energy conservation standards. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #6 at p. 2) The primary reason for excluding these pumps from this test procedure rulemaking is their low market share in the considered horsepower range and low potential for energy savings. (Docket No. EERE-2013-BT-NOC-0039, No. 14 at pp. 114 and 372–73) In addition, the CIP Working Group acknowledged that PD pumps are more commonly used in non-clean water applications and provide a different utility than the categories of pumps addressed in this rulemaking. (Docket No. EERE-2013-BT-NOC-0039, No. 14 at p. 114) Therefore, in the April 2015 pumps test procedure NOPR, DOE proposed to exclude these pumps from the scope of this rulemaking and the parallel energy conservation standards rulemaking, but determined that both axial/mixed flow and PD pumps were implicitly excluded based on the proposed equipment category definitions and scope parameters, so that explicit exclusions were not necessary. 80 FR 17586, 17597-98 (April 1, 2015). In the April 2015 pumps test procedure NOPR, DOE requested comment on the proposed exclusion and the assertion that such pumps were explicitly excluded based on the existing definitions and scope parameters. Id.

HI commented that both positive displacement and axial/mixed flow pumps should be added to the list of equipment excluded from the scope of pumps in this final rule. HI noted that PD pumps represent a small percentage of the overall pump market and are generally used for niche applications, such as viscous or shear-sensitive liquids. As a result, such pumps have a distinct difference in design compared with rotodynamic pumps. HI also suggested differentiating and excluding axial/mixed flow pumps using a specific speed limit of 4,500,[23] where pumps with a specific speed greater than 4,500 would be considered axial/mixed flow. (HI, No. 8 at p. 11)

In response to HI, DOE notes that the April 2015 pumps test procedure NOPR does not include PD pumps within its scope of applicability. All equipment to which the April 2015 pumps test procedure NOPR and this final rule applies is explicitly defined as types of rotodynamic pumps. Further, rotodynamic pumps are explicitly defined in the April 2015 pumps test procedure NOPR and this final rule as continuously imparting energy to the pumped fluid by means of a rotating impeller, propeller, or rotor. Such definition necessarily does not include PD pumps, which do not continuously impart energy to the pumped fluid and do not contain an impeller, propeller, or rotor. As such, no PD pumps meet the definition of any equipment within the scope of this test procedure, as discussed in section III.A.2.a. Therefore, DOE does not believe it is necessary to explicitly exclude PD pumps, which is consistent with the comments submitted by HI.

Regarding axial/mixed flow pumps, DOE agrees with HI that axial/mixed flow pumps, which are designed to accommodate high flow-to-head-ratio applications, should not be subject to the test procedure established in this final rule. DOE notes that the definitions of IL, RSV, and VTS implicitly exclude axial/mixed flow pumps through specific design features. Specifically, the definitions of IL and RSV pumps exclude

[23] Specific speed is a quasi-dimensionless quantity used to describe relative pump geometry and flow characteristics.

axial/mixed flow pumps by specifying single axis flow and a liquid inlet in a plane perpendicular to the impeller shaft. In contrast, the liquid intake in axial/mixed flow pumps is typically parallel to the impeller shaft; as such, these pumps do not meet the definition of an RSV or IL pump. DOE understands that less typical piping configurations could allow an axial/mixed flow pump to be built with the liquid inlet in a plane perpendicular to the impeller shaft. However, such a configuration would not satisfy the definition of single axis flow and, as such, these pumps would not meet the definition of an RSV or IL pump. Additionally, the definition of VTS pump excludes axial/mixed flow pumps by specifying that the pump must be designed to operate with the motor and stage(s) fully submerged in the pumped liquid. Axial/mixed flow pumps are not designed to be completely submerged in the pumped liquid and, therefore do not meet the definition of a VTS pump.

In summary, DOE believes that the definitions of IL, RSV, and VTS equipment categories are sufficient to exclude pumps that are referred to as axial/mixed flow. As a result, DOE maintains that a specific speed limitation or other criteria for these categories is unnecessary, and DOE has not included a specific speed range for these pumps in the parameters for establishing the scope of this rulemaking described in section III.A.4.

With respect to the end suction pumps defined in this final rule, DOE agrees that additional scope parameters are necessary to limit the scope of this rulemaking to end suction pumps and not inadvertently include axial/mixed flow pumps. DOE agrees with HI's suggestion of a specific speed limit to accomplish the exclusion of axial/mixed flow pumps. However, DOE reviewed the specific speeds of all end suction pumps submitted by manufacturers during the energy conservation standards rulemaking and identified multiple end suction pumps with specific speeds in the range of 4,500 to 5,000.[24] DOE notes these data were voluntarily submitted by manufacturers who self-classified their pumps into equipment types with the understanding that the rulemaking was not intended to include axial/mixed flow pumps. DOE reviewed literature for the specific pumps end suction pumps with specific speeds in the range of 4,500 to 5,000 and found them to be marketed as end suction pumps. Furthermore, DOE notes that the performance data for these pumps were included in the energy conservation standards rulemaking analysis. Consequently, DOE finds it appropriate to explicitly include within the scope of this rule, as established in 431.464(a)(1)(ii), all end suction pumps with specific speeds up to and including 5,000 and exclude pumps with specific speeds greater than 5,000.

e. Final Equipment Category Definitions

After consideration of all comments, definitions for pump equipment categories subject to this test procedure are as follows:

1) End suction close-coupled (ESCC) pump means a close-coupled, dry rotor, end suction pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and that is not a pool filter pump.

[24] All values for specific speed in this final rule pertain to calculations using U.S. customary units.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH7, as described in ANSI/HI 1.1-1.2–2014, within the specified horsepower range.

2) End suction frame mounted/own bearings (ESFM)[25] pump means a mechanically-coupled, dry rotor, end suction pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and that is not a pool filter pump.

   Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH0 and OH1, as described in ANSI/HI 1.1-1.2–2014, within the specified horsepower range.

3) In-line pump means a pump that is either

   a) a twin-head pump, or

   b) a single-stage, single-axis flow, dry rotor, rotodynamic pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter, in which liquid is discharged through a volute in a plane perpendicular to the shaft.

   Such pumps do not include pumps that are mechanically or close-coupled, have a pump power output that is less than or equal to 5 hp at BEP at full impeller diameter, and are distributed in commerce with a horizontal motor.

[25] While DOE has slightly modified the defined term from "end-suction frame mounted" to "end-suction frame mounted/own bearings" in this final rule, DOE continues to reference the abbreviation ESFM for consistency with nomenclature used to define such pumps up to this point in the April 2015 pump test procedure NOPR, the related energy conservation standards rulemaking (Docket No. EERE-2011-BT-STD-0031), and the CIP Working Group.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature OH3, OH4, or OH5, as described in ANSI/HI 1.1-1.2–2014, within the specified horsepower range.

4) Radially split, multi-stage, vertical, in-line, diffuser casing (RSV) pump means a vertically suspended, multi-stage, single axis flow, dry rotor, rotodynamic pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and for the number of stages required for testing and in which:

   a) liquid is discharged in a plane perpendicular to the impeller shaft;
   b) each stage consists of an impeller and diffuser; and
   c) no external part of such a pump is designed to be submerged in the pumped liquid.

   Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature VS8, as described in the ANSI/HI 2.1-2.2–2014).

5) Submersible turbine (VTS)[26] pump means a single-stage or multi-stage, dry rotor, rotodynamic pump that is designed to be operated with the motor and stage(s) fully submerged in the pumped liquid; that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and for the number of stages required for testing; and in which:

[26] While DOE has slightly modified the defined term from "vertical turbine submersible" to "submersible turbine" in this final rule, in the preamble DOE continues to reference the abbreviation VTS for consistency with nomenclature used to define such pumps up to this point in the April 2015 pump test procedure NOPR, the related energy conservation standards rulemaking (Docket No. EERE-2011-BT-STD-0031), and the CIP Working Group. However, in the regulatory text, DOE is using the acronym "ST" for long-term consistency with the defined term.

a) each stage of this pump consists of an impeller and diffuser and

b) liquid enters and exits each stage of the bare pump in a direction parallel to the impeller shaft.

Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature VS0, as described in ANSI/HI 2.1-2.2–2014.

In addition, DOE is adopting several definitions for terms used in the above equipment class definitions. DOE notes that that majority of these definitions were included verbatim in the equipment category definitions proposed in the April 2015 pumps test procedure NOPR and are generally consistent with the recommended definitions for such terms submitted by HI. As such, DOE believes that adopting these definitions does not change the scope of equipment for which this test procedure is applicable, but improves the legibility and clarity of the final equipment category definitions listed in this section.

Dry rotor pump means a pump in which the motor rotor is not immersed in the pumped fluid.

Horizontal motor means a motor that requires the motor shaft to be in a horizontal position to function as designed, as specified in manufacturer literature.

Close-coupled pump means a pump in which the motor shaft also serves as the impeller shaft for the bare pump.

Mechanically-coupled pump means a pump in which the bare pump has its own impeller shaft and bearings and so does not rely on the motor shaft to serve as the impeller shaft.

DOE received no comments on DOE's other supporting definitions proposed in the April 2015 pumps test procedure NOPR, namely rotodynamic pump, single axis flow pump, and end suction pump. Therefore, DOE is adopting those definitions as proposed.

3. Scope Exclusions Based on Application

In an effort to meet the intent and recommendations of the CIP Working Group to include only those pumps intended to pump clean water in the scope of this test procedure rulemaking (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #8 at pp. 3–4), DOE proposed to define "clean water pump" in the April 2015 pumps test procedure NOPR. 80 FR 17586, 17598 (April 1, 2015). DOE also proposed defining several kinds of clean water pumps that are designed for specific applications and that the CIP Working Group had indicated should be excluded from the scope of this test procedure and DOE's standards rulemaking efforts that are being considered in a separate rulemaking. (Docket No. EERE-2011-BT-STD-0031) These proposed definitions, comments DOE received regarding the proposed definitions, and DOE's responses to those comments are discussed in the subsequent sections III.A.3.a and III.A.3.b.

a. Definition of Clean Water Pump

In the NOPR, DOE proposed defining “clean water pump” as a pump that is designed for use in pumping water with a maximum non-absorbent free solid content of 0.25 kilograms per cubic meter, and with a maximum dissolved solid content of 50 kilograms per cubic meter, provided that the total gas content of the water does not exceed the saturation volume, and disregarding any additives necessary to prevent the water from freezing at a minimum of -10 °C. DOE also noted that several common pumps would not meet the definition of clean water pumps, as they are not designed for pumping clean water, including wastewater, sump, slurry, or solids handling pumps; pumps designed for pumping hydrocarbon product fluids; chemical process pumps; and sanitary pumps. DOE also proposed to incorporate by reference the definition for “clear water” established in HI 40.6–2014 to describe the characteristics of the fluid to be used when testing pumps in accordance with the DOE test procedure. 80 FR 17586, 17598 (April 1, 2015).

DOE requested comment on the definition of “clean water pump” proposed in the April 2015 pumps test procedure NOPR and its proposal to incorporate by reference the definition of “clear water” in HI 40.6–2014 to describe the testing fluid to be used when testing pumps in accordance with the DOE test procedure. In response to these proposals, HI commented that it agrees with the definition of “clean water pump” as set forth in the NOPR, and that it agrees with incorporating by reference the definition of “clear water” in HI 40.6–2014. (HI, No. 8 at p. 11) DOE received no other comments on these terms and has determined that the definitions proposed in the NOPR are sufficient for the purposes of applying DOE’s test procedure. However, for consistency, DOE is making the minor modification of translating the definition to use all U.S. customary units. As such, DOE is adopting the definition of clean water pump and incorporating by reference the definition of "clear water" in HI 40.6–2014 as proposed in the April 2015 pumps test procedure NOPR, with only the minor modification regarding units noted previously.

b. Exclusion of Specific Kinds of Clean Water Pumps

In the April 2015 pumps test procedure NOPR, DOE also proposed defining several kinds of pumps that meet the definition of clean water pumps discussed in section III.A.3.a, but that the CIP Working Group recommended be excluded from this pumps test procedure rulemaking. Specifically, in the April 2015 pump test procedure NOPR, DOE proposed that the test procedure would not apply to the following:

- fire pumps;
- self-priming pumps;
- prime-assist pumps;
- sealless pumps;
- pumps designed to be used in a nuclear facility subject to 10 CFR part 50—Domestic Licensing of Production and Utilization Facilities; and
- a pump meeting the design and construction requirements set forth in Military Specification MIL-P-17639F, "Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use" (as amended).

80 FR 17586, 17598-17600 (April 1, 2015).

Accordingly, DOE proposed the following definitions of fire pump, self-priming pump, prime-assist pump, and sealless pump:

- Fire pump means a pump that is compliant with National Fire Protection Association (NFPA) 20–2016,[27] "Standard for the Installation of Stationary Pumps for Fire Protection," and either (1) American National Standards Institute(ANSI)/UL listed under ANSI/UL 448-2013, "Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service," or (2) FM approved under the January 2015 edition[28] of FM Class Number 1319, "Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type)."
- Self-priming pump means a pump designed to lift liquid that originates below the center line of the pump impeller. Such a pump requires initial manual priming from a dry start condition, but requires no subsequent manual re-priming.
- Prime-assist pump means a pump designed to lift liquid that originates below the center line of the pump impeller. Such a pump requires no manual intervention to prime or re-prime from a dry-start condition. Such a pump

[27] DOE notes that in the April 2015 pumps test procedure NOPR, DOE proposed to reference NFPA 20-2013. However, on May 26, 2015, NFPA released a revised version of NFPA 20. DOE reviewed the new NFPA 20-2016 and finds it to be consistent with NFPA 20-2013 for the purposes of defining the characteristics of a "fire pump" in the context of DOE's regulations for pumps. DOE finds it most appropriate to reference the most up-to-date version of the NFPA Standard, as that version would be the version currently in use for specifying the necessary characteristics of fire pumps in the industry. Therefore, in this final rule, DOE is updating the definition of fire pump to reference NFPA 20-2016.

[28] Similar to NFPA 20-2016, DOE notes that, in January 2015, FM Global released an updated version of the FM Class Number 1319 standard. DOE reviewed the new January 2015 edition and notes that it contains only editorial changes as compared to the October 2008 edition proposed in the NOPR. DOE believes that it is most appropriate to reference the most up-to-date version of the FM standard, as that version is the version currently in use for specifying the necessary characteristics of fire pumps in the industry. Therefore, in this final rule, DOE is updating the definition of fire pump to reference the January 2015 edition of FM Class Number 1319.

includes a vacuum pump or air compressor to remove air from the suction line to automatically perform the prime or re-prime function.

- Sealless pump means either:
  - A pump that transmits torque from the motor to the bare pump using a magnetic coupling; or
  - A pump in which the motor shaft also serves as the impeller shaft for the bare pump, and the motor rotor is immersed in the pumped fluid.

Id. at 17641-42.

HI commented that it agrees with the definition of “fire pump” and recommended alternate definitions for “self-priming pump,” “prime-assist pump,” and “sealless pump” as follows:

- Self-priming pump means a pump designed to lift liquid that originates below the centerline of the pump inlet. Further, such a pump must contain at least one internal recirculation passage and requires a manual filling of the pump casing prior to initial start-up. Such a pump must then be able to re-prime after the initial start-up without the use of external vacuum sources, manual filling, or a foot valve.
- Prime-assist pump means a pump designed to lift liquid that originates below the centerline of the pump inlet. Such a pump requires no manual intervention to prime or re-prime from a dry-start condition without the use of a foot valve. Such a pump includes a vacuum pump or air compressor and venture/educator

to remove air from the suction line to automatically perform the prime or re-prime function at any point during the pump's operating cycle.

- A sealless pump means either:
  - A hermetically sealed pump that transmits torque from the motor to an inner impeller rotor via magnetic force through a containment shell;
  - Or, a type of pump that has a common shaft to link the pump and motor in a single hermetically sealed unit. The pumped liquid is circulated through the motor but is isolated from the motor components by a stator liner.

(HI, No. 55 at pp. 11–12)

DOE considered these recommendations and revised the definitions of these excluded clean water pumps in this final rule, incorporating the key components of HI's proposals. Specifically, DOE agrees with HI's revised definitions for prime-assist pump and self-priming pump and is adopting them in this final rule with some minor modifications for clarity. DOE finds HI's suggested definitions to be consistent with DOE's proposed definitions but more precise, using industry-specific language.

Regarding HI's suggested definition of sealless pump, DOE agrees with the content of the definition. However, DOE notes that, based on the modifications to equipment category definitions described in section III.A.2.a, DOE has determined that it is no longer necessary to explicitly exclude wet rotor pumps (the second clause of HI's sealless pump definition) from the scope of this rulemaking. Specifically, as explained in section III.A.2.a, DOE is specifying in its revised definitions that all ESCC, ESFM, IL, RSV, and VTS pumps are types of dry rotor pumps. Dry rotor pump means a pump in which the motor rotor is not immersed in the pumped fluid. Conversely, a wet rotor pump is one in which the motor rotor is immersed in the pumped liquid.

Given the mutually exclusive relationship between wet and dry rotor pumps, the definitions of ESCC, ESFM, IL, RSV, and VTS pumps, as established in section III.A.2.a, now implicitly exclude wet rotor pumps from the scope of this test procedure. As a result, DOE has simplified the sealless pump exclusion in this final rule to exclude magnet driven pumps only. Accordingly, DOE is also modifying the term “sealless pump” to “magnet driven pump,” as DOE believes this term more accurately describes the excluded equipment. In addition, DOE is modifying the definition of magnet driven pump to be consistent with the suggestions from HI, which DOE believes is consistent with the portion of the sealless pump definition proposed in the April 2015 pumps test procedure NOPR addressing magnet driven pumps, but which uses more precise and industry-specific terminology.

HI also commented that no pumps designed to the Federal defense specification MIL-P-17639 should be included in this rulemaking. (HI, No. 8 at p. 12) HI stated that the specifications included in the CIP Working Group term sheet also should be excluded, specifically MIL-P-17881, MIL-P-17840, MIL-P-18682, and MIL-P-18472 (commonly referred to as “MIL-SPEC”). DOE has therefore reviewed these additional specifications in determining exclusions in this final rule.

Pumps designed to these military specifications must meet very specific physical and/or operational characteristics and comply with complex and rigid reporting requirements.[29] These specifications require that significant amounts of design and test data be submitted to various military design review agencies to ensure that the pump can be operated and maintained in harsh naval environments. DOE believes there is sufficient justification to exclude all of the MIL-SPEC pumps identified by HI from the scope of this rulemaking without a risk of clean water pumps being marketed or sold as MIL-SPEC for actual use in other applications due to the rigorous and burdensome requirements associated with complying with those regulations. DOE notes that, as mentioned in the April 2015 pumps test procedure NOPR, when considering if a pump is designed and constructed to the requirements set forth in any of these specifications, DOE may request that a manufacturer provide DOE with copies of the original design and test data that were submitted to appropriate design review agencies, as required by each of these specifications. 80 FR 17586, 17599 (April 1, 2015).

After reviewing and considering comments, DOE is adopting in this final rule that the following specific types of clean water pumps are excluded from the scope of this test procedure final rule:

- fire pumps;
- self-priming pumps;
- prime-assist pumps;

[29] United States General Accounting Office, Report to Congressional Committees, Acquisition Reform: DOD Begins Program To Reform Specifications and Standards, GAO/NSIAD-95-14. October 11, 1994. Washington, DC. pp. 2–3. http://www.gao.gov/archive/1995/ns95014.pdf

- magnet driven pumps;
- pumps designed to be used in a nuclear facility subject to 10 CFR part 50—Domestic Licensing of Production and Utilization Facilities; and
- pumps meeting the design and construction requirements set forth in Military Specification MIL-P-17639F, "Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use" (as amended); MIL-P-17881D, "Pumps, Centrifugal, Boiler Feed, (Multi-Stage)" (as amended); MIL-P-17840C, "Pumps, Centrifugal, Close-Coupled, Navy Standard (For Surface Ship Application)" (as amended); MIL-P-18682D, "Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard" (as amended); and MIL-P-18472G, "Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, And Distilling Plant" (as amended).

Accordingly, DOE provides the following revised definitions of fire pump, self-priming pump, prime-assist pump, and magnet driven pump:

- <u>Fire pump</u> means a pump that is compliant with NFPA 20–2016, "Standard for the Installation of Stationary Pumps for Fire Protection," and either (1) UL listed under ANSI/UL448-2013, "Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service," or (2) FM approved under the January 2015 edition of FM Class Number 1319, "Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type)."
- <u>Self-priming pump</u> means a pump that (1) is designed to lift liquid that originates below the centerline of the pump inlet; (2) contains at least one

internal recirculation passage; and (3) requires a manual filling of the pump casing prior to initial start-up, but is able to re-prime after the initial start-up without the use of external vacuum sources, manual filling, or a foot valve.

- Prime-assist pump means a pump that (1) is designed to lift liquid that originates below the centerline of the pump inlet; (2) requires no manual intervention to prime or re-prime from a dry-start condition; and (3) includes a device, such as a vacuum pump or air compressor and venturi eductor, to remove air from the suction line in order to automatically perform the prime or re-prime function at any point during the pump's operating cycle.
- Magnet driven pump means a pump in which the bare pump is isolated from the motor via a containment shell and torque is transmitted from the motor to the bare pump via magnetic force. The motor shaft is not physically coupled to the impeller or impeller shaft. Magnet driven pumps are also commonly referred to as "mag-drive" pumps in industry.

4. Parameters for Establishing the Scope of Pumps in this Rulemaking

In addition to limiting the types of pumps that DOE will regulate at this time through pump definitions and their applications, DOE proposed in the April 2015 pumps test procedure NOPR to further limit the scope of the pumps test procedure considered in this rulemaking by applying the following performance and design characteristics:

- 1–200 hp (shaft power at the BEP at full impeller diameter for the number of stages[30] required for testing to the standard);[31]
- 25 gallons per minute (gpm) and greater (at BEP at full impeller diameter);
- 459 feet of head maximum (at BEP at full impeller diameter);
- design temperature range from -10 to 120 °C;
- pumps designed for nominal 3,600 or 1,800 revolutions per minute (rpm) driver speeds; and
- 6-inch or smaller bowl diameter for VTS pumps (HI VS0).

(Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #7 at p. 3);80 FR 17586, 17600 (April 1, 2015).

Wilo commented that lower thresholds for horsepower and BEP flow rate should not be included as limiting parameters on the scope of pumps considered in the rule, citing unspecified gains in energy savings that could be realized by regulating smaller models. (Wilo, Docket No. EERE-2011-BT-STD-0031, No. 44 at pp. 1–2)[32] In response to Wilo's suggestion that DOE apply the test procedure to pumps with flow rates below 25 gpm or shaft input power below 1 hp, DOE believes that such a recommendation is inconsistent with the scope of pumps the CIP Working Group recommended for this

---

[30] The number of "stages" in a multi-stage pump refers to the number of bowl assemblies included in that pump.

[31] The CIP Working Group also recommended that testing be required with three stages for RSV pumps and nine stages for VTS pumps, unless a model is not available with that specific number of stages, in which case the pump would be tested with the next closest number of stages. This recommendation is discussed in more detail in section III.C.2.c.

[32] A notation in this form provides a reference for information that is in the docket of DOE's rulemaking to develop energy conservation standards for commercial and industrial pumps (Docket No. EERE-2011-BT-STD-0031, which is maintained at www.regulations.gov). This particular notation refers to a comment: (1) submitted by Wilo; (2) appearing in document number 44 of the docket; and (3) appearing on pages 1-2 of that document.

rulemaking. Given that such small horsepower pumps were not considered in the CIP Working Group discussions, any data or information submitted to DOE throughout those negotiations did not consider small horsepower pumps. As such, DOE is electing to maintain the lower thresholds for horsepower and BEP flow rate as proposed in the April 2015 pumps test procedure NOPR.

HI recommended in the April 2015 NOPR public meeting and written comments that DOE establish scope related to "driver and impeller" speed rather than just driver speed. HI noted that pumps do not all have 1:1 motor rotating speed to impeller-rotating speed, such as a gear pump. (HI, NOPR public meeting transcript, No. 7 at p. 85; HI, No. 8 at p. 13) HI further specified as an example that a geared pump designed to use a 2-pole motor could be in scope but could not be tested according to section I.C.1 of the test procedure. (HI, No. 8 at p. 13)

DOE notes that the list shown in the preamble of the April 2015 pump test procedure NOPR, based on the CIP Working Group recommendations, included a limitation for pumps designed for nominal driver speeds of 3,600 or 1,800 revolutions per minute (rpm) driver. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #7 at p. 3); 80 FR 17586, 17600 (April 1, 2015). However, in the regulatory text of the April 2015 pumps test procedure NOPR, DOE modified this recommendation to acknowledge that the pumps within the scope of the proposed test procedure include pumps paired with non-induction motors, which have wide range of operating speeds. Specifically, DOE proposed to limit the scope of the proposed test procedure to pumps designed to operate with either: (1) a 2- or 4-pole induction motor, or (2) a non-induction motor with a speed of rotation operating range that includes speeds of rotation between 2,880 and 4,320 rpm and/or 1,440 and 2,160 rpm. Id. at 17642. DOE proposed the speed ranges of 2,880 to 4,320 and 1,440 to 2,160 based on the nominal rotating speeds of 3,600 and 1,800 for 2- and 4-pole motors, respectively, and the allowed 20 percent tolerance on rotating speed proposed in the NOPR. Id. at 17609.

DOE notes that geared pumps were never explicitly addressed by the CIP Working Group; were not included in the pump data which are the basis of this final rule and the associated energy conservation standard rulemaking; and were not intended to be included in the scope of the April 2015 pumps test procedure NOPR. In addition, as mentioned in section III.A.2.a, geared pumps typically operate at impeller speeds higher than the 1,800 and 3,600 nominal rotating speeds DOE referenced in CIP Working Group discussions and the April 2015 pumps test procedure NOPR. In light of HI's comment, DOE agrees that it is worth clarifying that such pumps are not subject to or addressed by the test procedure established in this final rule. To clarify that pumps with higher impeller or lower driver rotating speeds (i.e., geared pumps) are not within the scope of this rulemaking, DOE is modifying the language establishing the rotating speeds within the scope of the test procedure adopted in this final rule to note that the driver and impeller must operate at the same speed.

During the April 2015 NOPR public meeting, the CA IOUs expressed concern regarding whether it was the CIP Working Group's intention to address VTS pumps that operate at high speed. Specifically, the CA IOUs mentioned that it may not have been the intent of HI to exclude a product operating at a higher rpm and recommended that HI consider the language proposed in the April 2015 pumps test procedure NOPR to ensure they support the scope of pumps addressed by the proposed test procedure. (CA IOUs, NOPR public meeting transcript, No. 7 at pp. 86–88) However, in its written comments, HI did not recommend any changes to the parameters other than the discussion on impeller speed versus driver speed. (HI, No. 8 at p. 13)

Wilo commented that manufacturers may redesign to nominal speeds excluded from the DOE regulation. (Wilo, Docket No. EERE-2011-BT-STD-0031, No. 44 at p. 2) Wilo indicated that, for example, a pump could be designed for use with 6-pole motors at 1,200 rpm, or for use with controls at 2,650 rpm. Wilo recommended to instead apply the minimum efficiency required per equipment class (e.g., C-values at 1,800 rpm) to pumps of any speed and specific speed, thereby eliminating exceptions for speed and allowing for enforcement across all motor speeds. (Id.)

DOE's data and analysis are based solely on pumps with nominal rotating speeds corresponding to those speed ranges proposed in the 2015 pumps test procedure NOPR. DOE notes that, during the initial data request underlying the parallel pumps test procedure and energy conservation standards rulemakings, DOE requested data on six-pole pumps from manufacturers. However, manufacturers declined to provide such on the basis that, while some pumps may be sold for use with 6-pole motors, they are all designed for use with 4- or 2-pole motors. (Docket No. EERE-2013-BT-NOC-0039, No.

46 at p. 198) As such, manufacturers posited that these pumps would already be captured in the provided data for 4- and 2-pole, and any efficiency improvements made to meet the energy conservation standards for those equipment classes would also result in energy savings when the pump was operated with a 6-pole motor. Additionally, DOE finds it unlikely that, for those pumps that can operate with 2-, 4-, or 6-pole motors, a manufacturer would begin specifying that their pump was inappropriate for operation in the nominal speed ranges of 2,880 and 4,320 rpm and/or 1,440 and 2,160 rpm to avoid regulation.

After considering these comments, DOE maintains its position set forth in the NOPR, and limits the test procedure applicability to pumps designed for the given motors or speeds. DOE notes that pumps with lower or higher operating speeds are covered as "pumps" and, should DOE deem it necessary, DOE could evaluate the need for a test procedure or standards for pumps at other rotating speeds in a future rulemaking.

In summary, DOE is establishing in this final rule the following scope parameters:

- 25 gpm and greater (at BEP at full impeller diameter);
- 459 feet of head maximum (at BEP at full impeller diameter and the number of stages specified for testing);
- design temperature range from 14 to 248 °F;
- designed to operate with either (1) a 2- or 4-pole induction motor, or (2) a non-induction motor with a speed of rotation operating range that includes

speeds of rotation between 2,880 and 4,320 rpm and/or 1,440 and 2,160 rpm, and in either case, the driver and impeller must rotate at the same speed; and

- 6-inch or smaller bowl diameter for VTS pumps (HI VS0).

As discussed further in section III.B.2, DOE is clarifying that the limitation on pump total head of 459 feet must be ascertained based on the pump operating at BEP, at full impeller diameter, and with the number of stages specified for testing.

Additionally, to exclude axial/mixed flow pumps, DOE is applying a seventh scope parameter for ESCC and ESFM pumps, namely:

- For ESCC and ESFM pumps, specific speed less than or equal to 5,000 when calculated using U.S. customary units in accordance with the DOE test procedure.

As discussed in section III.A.2.d, DOE is setting this limit on specific speed based on HI's suggestion and data submitted by manufacturers for end suction pumps. DOE believes that a specific speed limit for the remaining equipment categories, namely IL, RSV, and VTS, are unnecessary, as the definitions for these categories include design features that implicitly exclude axial/mixed flow pumps.

In the April 2015 pumps test procedure NOPR, DOE proposed defining bowl diameter to specify clearly and unambiguously the limiting criterion for VTS pumps (i.e., bowl diameter). 80 FR 17586, 17600 (April 1, 2015). Specifically, DOE proposed defining "bowl diameter" as it applies to VTS pumps as follows:

Bowl diameter means the maximum dimension of an imaginary straight line passing through and in the plane of the circular shape of the intermediate bowl or chamber of the bare pump that is perpendicular to the pump shaft and that intersects the circular shape of the intermediate bowl or chamber of the bare pump at both of its ends, where the intermediate bowl or chamber is as defined in ANSI/HI 2.1-2.2–2008.

With this definition, only those VTS pumps with bowl diameters of 6 inches or less would be required to be tested under the test procedure. Id.

In response to DOE's request for comment on the proposed definition for "bowl diameter" as it would apply to VTS pumps, HI commented that the definition should reference the updated 2014 version of ANSI/HI 2.1-2.2–2008, and recommended that the word "outermost" should be inserted before the text "circular shape of the intermediate bowl." (HI, No. 8 at p. 13) Based on previously submitted HI comments regarding the energy conservation standards rulemaking for pumps, DOE understands that VTS (e.g., VS0) pumps are considered equivalent to a style of pump referred to as "submersible multi-stage water pump" (MSS) in EU regulation 547.[33] (HI, Docket No. EERE-2011-BT-STD-0031, No. 25 at p. 3) DOE also understands that, according to EU 547, MSS

[33] Council of the European Union. 2012. Commission Regulation (EU) No 547/2012 of 25 June 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps. Official Journal of the European Union. L 165, 26 June 2012.

pumps are designed to be operated in a borehole and have a nominal outer diameter of either 4 or 6 inches.

DOE agrees with HI that including the word "outermost" in the proposed bowl diameter definition would improve the clarity of the critical dimension and ensure the definition is aligned with how the pumps are treated in EU 547. Therefore, in this final rule, DOE is including the term outer diameter before the text "circular shape of the intermediate bowl" in the definition of "bowl diameter" proposed in the April 2015 pumps test procedure NOPR. DOE has also determined that in order to avoid confusion with the ANSI/HI 2.1-2.2–2014 term "seal chamber," the text "or chamber" should be removed from the bowl diameter definition. The revised definition reads as follows:

Bowl diameter means the maximum dimension of an imaginary straight line passing through and in the plane of the circular shape of the intermediate bowl of the bare pump that is perpendicular to the pump shaft and that intersects the outermost circular shape of the intermediate bowl of the bare pump at both of its ends, where the intermediate bowl is as defined in ANSI/HI 2.1-2.2–2014.

5. Drivers other than Electric Motors

DOE recognizes that some pumps, particularly in the agricultural sector, may be sold and operated with drivers other than electric motors (i.e., non-electric drivers), such as engines, steam turbines, or generators. In the April 2015 pump test procedure NOPR, in accordance with the recommendations of the CIP Working Group (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #3 at p. 2), DOE proposed that pumps sold with non-electric drivers be rated as bare pumps only. Specifically, based on DOE's proposed test procedure for bare pumps discussed in detail in section III.E.1.a, pumps sold with non-electric drivers would determine the PEI_{CL} for the pump based on the calculated performance of the bare pump combined with a default motor that is minimally compliant with DOE's energy conservation standards for electric motors[34] listed at 10 CFR 431.25. 80 FR 17586, 17600 (April 1, 2015). DOE noted that by requiring testing and certification in this manner, any hydraulic improvements made to the bare pump to comply with any applicable energy conservation standards that may apply to the bare pump would also result in energy savings when the pump was used with a non-electric driver. Id.

DOE requested comment on its proposal to test pumps sold with non-electric drivers as bare pumps. HI commented that it agrees that pumps sold with non-electric drivers should be tested as bare pumps, as recommended by the CIP Working Group. (HI, No. 8 at p. 13) DOE received no other comments on the proposal and is adopting provisions for testing pumps paired with non-electric drivers as bare pumps in this final rule, as proposed in the April 2015 pumps test procedure NOPR.

6. Pumps Sold with Single-Phase Induction Motors

In the April 2015 pumps test procedure NOPR, DOE acknowledged that some pumps within the scope of this rulemaking may be distributed in commerce with single-phase motors. However, DOE determined that the majority of pumps in the scope of this

[34] In context, the terms "electric motor" and "motor" are used interchangeably.

test procedure rulemaking are sold with polyphase induction motors. Moreover, DOE noted that, to the extent that pumps within the scope of the proposed test procedure are distributed in commerce with single-phase motors, most of these pumps are offered for sale with either single-phase or polyphase induction motors of similar size, depending on the power requirements of customers.

Given that single-phase induction motors are, in general, less efficient than polyphase induction motors and, thus, will result in different energy consumption characteristics when paired with the same bare pump, DOE proposed that pumps sold with single-phase induction motors be tested and rated in the bare pump configuration, using the calculation-based method (see section III.E.1.a for a more detailed description of this method). DOE believed that such an approach would more equitably rate pumps sold with single-phase motors and prevent pumps sold with single-phase motors from being penalized by the reduced energy efficiency of the paired single-phase motor, as compared to similarly-sized polyphase motors. 80 FR 17586, 17600-01 (April 1, 2015).

In response to DOE's proposed method for testing pumps sold with single-phase induction motors, HI agreed that it is appropriate to apply the calculation-based test procedure to bare pumps to determine the PEI_{CL} for such pumps. However, HI also requested the option of using single-phase motor wire-to-water test data (that is, applying the testing-based method for pumps sold with motors, discussed in section III.E.2.b) to determine the PEI_{CL} for such pumps. (HI, No. 8 at p. 13) Given that single-phase induction motors are, in general, less efficient than polyphase induction motors, determining the PEI_{CL} for pumps sold with single-phase induction motors based on the testing-based method for pumps sold with motors will generally result in PEI_{CL} ratings that are equivalent to or lower than those determined by rating the pump as a bare pump (as proposed in the April 2015 pumps test procedure NOPR). Therefore, use of the testing-based method will make it harder, rather than easier, for pumps sold with single-phase induction motors, to meet the established standards. For these reasons, DOE sees no reason why manufactures could not be allowed to employ the testing-based method for pumps sold with motors to determine the PEI_{CL} if they chose to. As such, DOE is adopting provisions in this final rule that allow manufacturers the option of rating pumps sold with single-phase motors as bare pumps (using a calculation-based method) or as pumps with motors using the testing-based methods. DOE notes that if manufacturers choose to employ the testing-based methods for pumps sold with motors, the denominator must still be calculated based on the default motor efficiency values for polyphase NEMA Design B motor, as discussed in section III.B.2. DOE also notes that, as for all pumps subject to this test procedure final rule, manufacturers must report which test method was employed in determining the certified PEI_{CL} rating for the given basic model in the certification report submitted to DOE. These requirements are discussed in more detail in the pumps energy conservation standards rulemaking. (Docket No. EERE-2011-BT-STD-0031)

B. Rating Metric: Constant and Variable Load Pump Energy Index

After significant discussion in the CIP Working Group open meeting, the Working Group recommended that DOE use a wire-to-water, power-based metric for all pumps, regardless of how they are sold. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #11 at p. 5) Specifically, the CIP Working Group recommended that DOE use the PEI metric to measure pump energy performance, which is calculated as a ratio of the PER (PER_{CL} or PER_{VL}) of the tested pump divided by the PER_{CL} of a pump that would minimally comply with any DOE energy conservation standard for that pump type (PER_{STD}). In both cases, PER represents a pump's power consumption at a weighted average of three or four load points. The CIP Working Group recommended a similar metric for all pump configurations (i.e., bare pumps, pumps sold with a motor, and pumps sold with a motor and continuous or non-continuous controls) to allow for better comparability and more consistent application of the rating metric for all pumps within the recommended scope. This way, the benefit of speed control, as compared to a similar pump without speed control, can be reflected in the measurement of energy use or energy efficiency.

Accordingly, in the April 2015 pumps test procedure NOPR, DOE proposed to establish a test procedure to determine the PEI_{CL} for pumps sold without continuous or non-continuous controls and PEI_{VL} for pumps sold with continuous or non-continuous controls. 80 FR 17586, 17601-02 (April 1, 2015). As recommended by the CIP Working Group, DOE proposed to determine the PEI_{CL} or PEI_{VL} as the ratio of a PER_{CL} or PER_{VL} scaled with respect to a "standard pump energy rating" (PER_{STD}) that represents the performance of a bare pump of the same equipment class that serves the same hydraulic load, has the same flow and specific speed characteristics, and is minimally compliant with DOE's energy conservation standards. Id.

Specifically, for pumps sold without continuous or non-continuous controls, DOE proposed using the PEI_{CL} metric, which would be evaluated as shown in equation (1):

$$\mathrm{PEI_{CL}} = \frac{\mathrm{PER_{CL}}}{\mathrm{PER_{STD}}} \qquad \textbf{(1)}$$

Where:

PER_{CL} = the weighted average input power to the motor at load points of 75, 100, and 110 percent of BEP flow (hp) and

PER_{STD} = the PER_{CL} for a pump of the same equipment class with the same flow and specific speed characteristics that is minimally compliant with DOE's energy conservation standards serving the same hydraulic load (hp). A more detailed discussion of the PER_{STD} value is provided in section III.B.2.

Similarly, for pumps sold with a motor and continuous or non-continuous controls, DOE proposed to use PEI_{VL}, which would be evaluated as shown in equation (2):

$$\mathrm{PEI_{VL}} = \frac{\mathrm{PER_{VL}}}{\mathrm{PER_{STD}}} \qquad \textbf{(2)}$$

Where:

PER_{VL} = the average input power to the motor and continuous or non-continuous controls at load points of 25, 50, 75, and 100 percent of BEP flow (hp) and

PER_{STD} = the PER_{CL} for a pump of the same equipment class with the same flow and specific speed characteristics that is minimally compliant with DOE's energy conservation standards serving the same hydraulic load (hp).

DOE noted in the April 2015 pumps test procedure NOPR that, under the proposed approach, the performance of bare pumps or pumps paired with motors (but without continuous or non-continuous controls) would be determined for the appropriate load points along the single-speed pump curve by increasing head (i.e., throttling) as flow is decreased from the maximum flow rate of the pump, while pumps sold with continuous or non-continuous controls, by contrast, would follow a system curve and achieve the desired flow points by reducing the pump's speed of rotation rather than controlling flow by throttling. By reducing speed, power is reduced in proportion to the cube of speed, resulting in lower power requirements for any part load flow points. As such, the PEI_{VL} for a pump sold with continuous or non-continuous controls would be lower than the PEI_{CL} for the same pump sold without continuous or non-continuous controls. In essence, consistent with the recommendation of the CIP Working Group, adopting the PEI_{CL} and PEI_{VL} metrics as proposed would illustrate the inherent performance differences that can occur when coupling a given pump with continuous or non-continuous controls. Id.

1. Determination of the Pump Energy Rating

As mentioned above, PER_{CL} and PER_{VL} represent the weighted average input power to the pump determined at three or four discrete load points for PER_{CL} or PER_{VL}, respectively. In order to determine the representative performance of a given pump unit, DOE must define a load profile and establish specific load points at which to test a given pump for pumps sold with speed controls and pumps sold without such speed controls (i.e., pumps sold as bare pumps and pumps sold with motors). Based on DOE's research and recommendations provided by the CIP Working Group, DOE proposed adopting two distinct load profiles to represent constant speed and variable speed pump operation, as shown in Table III.2.

Table III.2 Load Profiles Based on Pump Configuration

Pump Configuration	Load Profile	Load Points
Pumps Sold without Continuous or Non-Continuous Controls (i.e., bare pumps and pumps sold with motors)	Constant Load Profile	75%, 100%, and 110% of BEP flow
Pumps Sold with Continuous or Non-Continuous Controls	Variable Load Profile	25%, 50%, 75%, and 100% of BEP flow

Lack of field data on load profiles and the wide variation in system operation also make it difficult to select appropriate weights for the load profiles. For these reasons, the CIP Working Group members concluded that equal weighting would at least create a level playing field across manufacturers (see, e.g., Docket No. EERE-2013-BT-NOC-0039, No. 63 at p. 125), and DOE proposed to adopt this recommendation in the April 2015 pumps test procedure NOPR. 80 FR 17586, 17604 (April 1, 2015).

In response to DOE's proposed metrics, load points, and weights, HI commented that it agrees with the PEI_{CL} and PEI_{VL} metric architecture (HI, No. 8 at p. 14), and the CA IOUs also indicated their support of DOE's proposed approach (CA IOUs, NOPR public meeting transcript, No. 7 at p. 110). Therefore, DOE is adopting, in this final rule, a metric of PEI_{CL} for pumps sold as bare pumps or pumps sold with motors, but without continuous or non-continuous controls, as proposed in the April 2015 pumps test procedure NOPR, where the PER_{CL} would be evaluated as the weighted average input power to the motor at load points corresponding to 75, 100, and 110 percent of BEP flow, as shown in equation (3):

$$\mathrm{PER_{CL}} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

$$= \omega_{75\%}\left(P_{75\%}^{in,m}\right) + \omega_{100\%}\left(P_{100\%}^{in,m}\right) + \omega_{110\%}\left(P_{110\%}^{in,m}\right)$$

$$= 0.3333 \times \left(P_{75\%}^{in,m}\right) + 0.3333 \times \left(P_{100\%}^{in,m}\right) + 0.3333 \times \left(P_{110\%}^{in,m}\right) \quad \textbf{(3)}$$

Where:

ω_i = weighting at load point i (equal weighting or 0.3333 in this case),

$P_i^{in,m}$ = measured or calculated driver power input to the motor at load point i (hp), and

i = load point corresponding to 75, 100, or 110 percent of BEP flow as determined in accordance with the DOE test procedure.

Id. at 17602.

Similarly, DOE is adopting a metric of PEI_{VL} for pumps sold with motors and continuous or non-continuous controls, where PER_{VL} is calculated as shown in equation (4):

$$\mathrm{PER_{VL}} = \sum_{i=25\%,50\%,75\%,100\%} \omega_i P_i^{in,c}$$

$$= \omega_{25\%}\left(P_{25\%}^{in,c}\right) + \omega_{50\%}\left(P_{50\%}^{in,c}\right) + \omega_{75\%}\left(P_{75\%}^{in,c}\right) + \omega_{100\%}\left(P_{100\%}^{in,c}\right)$$

$$= 0.25 \times \left(P_{25\%}^{in,c}\right) + 0.25 \times \left(P_{50\%}^{in,c}\right) + 0.25 \times \left(P_{75\%}^{in,c}\right) + 0.25 \times \left(P_{100\%}^{in,c}\right) \quad \textbf{(4)}$$

Where:

ω_i = weighting at load point i (equal weighting or 0.25 in this case),

$P_i^{in,c}$ = measured or calculated driver power input to the continuous or non-continuous controls at load point i (hp), and i = load point corresponding to 25, 50, 75, or 100 percent of BEP flow as determined in accordance with the DOE test procedure.

Id. at 17603.

DOE notes that, in the April 2015 pumps test procedure NOPR, DOE proposed to refer to the driver power input using the variable P_i^{in} regardless of whether it applied to pumps sold with motors, where the driver input power is measured at the input to the motor, or pumps sold with motors and continuous or non-continuous controls, where the driver power input is measured at the input to the controls. In this final rule, DOE is clarifying the terminology by referring to driver power input to the motor as $P_i^{in,m}$ and driver power input to the controls as $P_i^{in,c}$. DOE notes that HI 40.6−2014 uses the variable P_{gr} to refer to driver input power and, for the purposes of applying HI 40.6−2014 and the DOE test procedure, DOE's defined variable (i.e., $P_i^{in,m}$ and $P_i^{in,c}$) should be treated as equivalent to P_{gr}.

2. PER_{STD}: Minimally Compliant Pump

DOE proposed in the April 2015 pumps test procedure NOPR that the PER_{CL} or PER_{VL} of the pump being rated in the numerator of these equations would be scaled based on PER_{CL} of a pump that would minimally comply with the applicable standard for the same class of pump to provide a rating for each pump model that is indexed to a standardized value. DOE noted that scaling the PEI_{CL} and PEI_{VL} metrics based on a normalizing factor would help compare values across and among various pump types and sizes. 80 FR 17586, 17604 (April 1, 2015). DOE noted that such an approach would be consistent with the CIP Working Group's recommendations (Docket No. EERE-2013-

BT-NOC-0039, No. 92, Recommendation #11 at pg. 5) and is similar to the approach suggested by Europump, a trade association of European pump manufacturers.[35] Id.

In the April 2015 pumps test procedure NOPR, DOE proposed to determine PER_{STD} as a baseline, minimally compliant pump, inclusive of a minimally compliant default motor, defined as a function of flow and specific speed. To do this, DOE proposed to use an equation to determine the efficiency of a minimally compliant pump, shown in equation (5):[36]

$$\eta_{pump,STD} = -0.85 * \ln(Q_{100\%})^2 - 0.38 * \ln(Ns) * \ln(Q_{100\%}) - 11.48 * \ln(Ns)^2 + 17.80 * \ln(Q_{100\%}) + 179.80 * \ln(Ns) - (C + 555.6) \quad \textbf{(5)}$$

Where:

$Q_{100\%}$ = BEP flow rate (gpm),

Ns = specific speed at 60 Hz and calculated using U.S. customary units, and

C = a constant that is set for the two-dimensional surface described by equation (5), which is set based on the speed of rotation and equipment type of the pump model. The values of this constant, or "C-values," are used to establish the minimum, mandatory pump efficiency with a minimally compliant pump and will be established in the pump energy conservation standard rulemaking.

[35] Europump. Extended Product Approach for Pumps: A Europump Guide. April 8, 2013.

[36] This equation reflects that shown in the April 2015 NOPR public meeting (Docket No. EERE-2013-BT-TP-0055, No. 6 at p.49) and represents a correction from that published in the April 2015 pumps test procedure NOPR. 80 FR 17586, 17604 (April 1, 2015).

DOE developed this equation based on the equation used in the EU to develop its regulations for clean water pumps, translated to 60 Hz electrical input power and U.S. customary units.[37] Id. HI commented that it agrees with the corrected version of the equation for minimum pump efficiency equation ($\eta_{pump,STD}$) presented during the public meeting, except that the 555.6 value should be changed to 555.60 and a full significant digit analysis should be conducted to ensure that two decimal places can be carried for efficiency. (HI, No. 8 at pp. 14–15) HI also indicated that because all data in the equation are supposed to be normalized to 1,800 or 3,600 rpm, $Q_{100\%}$ should be clarified as the flow at BEP in gallons per minute normalized to synchronous speed at 60 Hz. In response to HI's suggested clarifications to the pump efficiency equipment presented in the April 2015 pump test procedure NOPR and the slide deck presented at the NOPR public meeting (see Docket No. EERE-2013-BT-TP-0055, No. 6 at p.49), DOE is clarifying in this final rule that $Q_{100\%}$ in the minimum pump efficiency equation ($\eta_{pump,STD}$) is the BEP flow rate (gpm) measured at 60 Hz and full impeller diameter and normalized to nominal speed of rotation of the pump (1,800 or 3,600 rpm). DOE has also revised the equation for minimum pump efficiency equation ($\eta_{pump,STD}$) to match the equation shared during the public meeting, as suggested by HI.

Regarding the significance of the 555.6 value in equation (5) and its impact on the number of significant digits in the resultant minimally compliant pump efficiency

[37] The equation to define the minimally compliant pump in the EU is of the same form, but employs different coefficients to reflect the fact that the flow will be reported in m^3/h at 50 Hz and the specific speed will also be reported in metric units. Specific speed is a dimensionless quantity, but has a different magnitude when calculated using metric versus U.S. customary units. DOE notes that an exact translation from metric to U.S. customary units is not possible due to the logarithmic relationship of the terms.

($\eta_{pump,STD}$) or final determination of PEI_{CL} or PEI_{VL}, DOE notes that all coefficients in the listed equations in DOE's pump test procedure, including the equation for the minimally compliant pump efficiency, should be treated as infinitely significant and should not limit the number of significant digits reported in the resultant value. As noted in the April 2015 pumps test procedure NOPR and discussed in more detail in section III.C.2.f, all calculations should be performed with raw measured values and rounded only when determining PER_{CL} or PER_{VL} and PEI_{CL} or PEI_{VL}. 80 FR 17586, 17612 (April 1, 2015) However, considering HI's comment, DOE acknowledges that testing personnel or manufacturers may inadvertently interpret equation coefficients to be reflective of a given degree of resolution, precision, or significance. Therefore, to ensure that, even if the coefficients are incorrectly treated as carrying an indication of measurement resolution or precision such rounding does not impact the significance of the reported PER_{CL} and PEI_{CL} or PER_{VL} and PEI_{VL} values, DOE is adding values (zeros in most cases) after the decimal to some of the coefficients in the minimally compliant pump efficiency equation, as shown in equation (6):

$$\eta_{pump,STD} = -0.8500 * \ln(Q_{100\%})^2 - 0.3800 * \ln(Ns) * \ln(Q_{100\%}) - 11.480 * \ln(Ns)^2 + 17.800 * \ln(Q_{100\%}) + 179.800 * \ln(Ns) - (C + 555.60) \quad \textbf{(6)}$$

Where:

$Q_{100\%}$ = BEP flow rate measured at full impeller diameter and normalized to the nominal speed of rotation for the tested pump (gpm),

Ns = specific speed at 60 Hz and calculated using U.S. customary units, and

C = a constant that is set for the two-dimensional surface described by equation (6) based on the speed of rotation and equipment type of the pump model. This constant, or "C-value," is used to establish the minimum, mandatory pump efficiency with a minimally compliant pump and will be established in the pump energy conservation standard rulemaking.

DOE added sufficient significant digits to ensure efficiency can be reported to 4 significant digits (i.e., the hundredths place for efficiencies greater than 10 percent). DOE is also adding zeros to the equations for calculating the reference system curve (described in section III.E.1.c) to similarly ensure sufficient significance is maintained throughout DOE's test procedure calculations.

In equation (6), the specific speed (N_s) is a quasi-non-dimensional number used to classify pumps based on their relative geometry and hydraulic characteristics. It is calculated as a function of the rotational speed, flow rate, head of the pump, and number of stages as shown in equation (7) below:

$$N_s = \frac{n_{sp} \times \sqrt{Q_{100\%}}}{(H_{100\%}/S)^{0.75}} \quad \textbf{(7)}$$

Where:

N_s = specific speed,

n_{sp} = nominal speed of rotation (rpm),

$Q_{100\%}$ = BEP flow rate at full impeller and nominal speed (gpm),

$H_{100\%}$ = pump total head at BEP flow at full impeller and nominal speed (ft), and

S = number of stages.

DOE notes that, in the April 2015 pumps test procedure NOPR, the definition of specific speed did not indicate that the $H_{100\%}$ term should be normalized by the number of stages. 80 FR 17586, 17604 (April 1, 2015). However, doing so is consistent with the theoretical calculation of specific speed for multi-stage pumps used in the pump industry,[38] as well as the CIP Working Group discussions and analysis[39] and treatment in the EU 547 regulations.[40] DOE also noted this in the second footnote to Table 1.2 in the Framework document. (Docket No. EERE-2011-BT-STD-0031, No. 13 at p. 7) To clarify that, for multi-stage RSV and VTS pumps the specific speed should be calculated for a single stage only, DOE is modifying equation (7) to clearly specify that the head at BEP should be divided by the number of stages with which the pump is being tested. Further, DOE also proposed using the capital letter "N" to define nominal speed of rotation. DOE notes that HI 40.6-2014 defines the "specified speed of rotation" using the nomenclature "n_{sp}." While DOE believes that the phrase "nominal speed of rotation" is clearer and more consistent with DOE's regulatory approach, DOE believes referencing the same nomenclature as HI 40.6-2014 will reduce confusion when conducting the pumps test procedure. As such, in this final rule, DOE is updating the variable used for nominal speed of rotation to be consistent with HI 40.6-2014.

---

[38] Wilson, S. Specific Speed. Grundfos White Paper. Available at: http://www.grundfos.com/content/dam/CBS/global/whitepapers/Specific-Speed.pdf

[39] DOE's PEI Calculator that was used to support Working Group negotiations and analysis divided the pump total head at 100 percent of BEP flow by the number of stages for multi-stage pumps (See, for example, Docket No. EERE-2013-BT-NOC-0039, No. 95).

[40] Council of the European Union. 2012. Commission Regulation (EU) No 547/2012 of 25 June 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps. Official Journal of the European Union. L 165, 26 June 2012.

As proposed in the April 2015 pumps test procedure NOPR, the calculated efficiency of the minimally compliant pump reflects the pump efficiency at BEP. To calculate PER_{STD} as the weighted average input power to a minimally compliant bare pump at the same load points as PER_{CL}, DOE determined a method to translate the default efficiency of a minimally compliant pump at BEP to the load points corresponding to 75 and 110 percent of BEP flow, as shown in equation (8):

$$\mathrm{PER_{STD}} = \sum_{i=75\%,100\%,110\%} \omega_i \left(\frac{\mathrm{P_{u,i}}}{\alpha_i \times \left[\eta_{\mathrm{pump,STD}} / 100 \right]} + \mathrm{L}_i \right)$$

$$= \omega_{75\%} \left(\frac{\mathrm{P_{u,75\%}}}{0.947 \times \left[\eta_{\mathrm{pump,STD}} / 100 \right]} + \mathrm{L}_{75\%} \right) + \omega_{100\%} \left(\frac{\mathrm{P_{u,100\%}}}{1.000 \times \left[\eta_{\mathrm{pump,STD}} / 100 \right]} + \mathrm{L}_{100\%} \right)$$

$$+ \omega_{110\%} \left(\frac{\mathrm{P_{u,110\%}}}{0.985 \times \left[\eta_{\mathrm{pump,STD}} / 100 \right]} + \mathrm{L}_{110\%} \right) \quad \mathbf{(8)}$$

Where:

ω_i = weighting at load point i (equal weighting or 0.3333 in this case);

$P_{u,i}$ = the measured hydraulic output power at load point i of the tested pump (hp);[41]

α_i = 0.947 for 75 percent of the BEP flow rate, 1.000 for 100 percent of the BEP flow rate, and 0.985 for 110 percent of the BEP flow rate;

$\eta_{pump,STD}$ = the minimally compliant pump efficiency, as determined in accordance with equation (6);

L_i = the motor losses at load point i, as determined in accordance with the procedure specified for bare pumps in sections III.D.1 and III.D.2; and

[41] In the April 2015 pumps test procedure NOPR, DOE proposed to define pump hydraulic output power using the variable nomenclature P_{Hydro}. However, HI 40.6-2014 uses the nomenclature P_u to refer to pump hydraulic output power. Therefore, for consistency, DOE is adopting the nomenclature P_u for hydraulic output power in this final rule.

i = load point corresponding to 75, 100, or 110 percent of BEP flow, as determined in accordance with the DOE test procedure.

80 FR 17586, 17605 (April 1, 2015).

DOE also proposed in the April 2015 pumps test procedure NOPR that the quotient of the hydraulic output power divided by the minimally compliant pump efficiency for the rated pump would be used to determine the input power to a minimally compliant pump at each load point, and that the pump hydraulic output power for the minimally compliant pump would be the same as that for the particular pump being evaluated. Specifically, DOE proposed that the hydraulic power in equation (8) at 75, 100, and 110 percent of BEP flow would be calculated using the following equation (9):

$$P_{u,i} = \frac{Q_i \times H_i \times SG}{3956} \quad \textbf{(9)}$$

Where:

$P_{u,i}$ = the measured hydraulic output power at load point i of the tested pump (hp);

Q_i = the measured flow rate at load point i of the tested pump (gpm);

H_i = pump total head at load point i of the tested pump (ft);

i = load point corresponding to 75, 100, or 110 percent of BEP flow, as determined in accordance with the DOE test procedure; and

SG = the specific gravity of water at specified test conditions.[42]

Id.

[42] DOE notes that the specific gravity of the test liquid specified in the DOE test procedure, which is clear water as defined by section 40.6.5.5 of HI 40.6–2014, requires that the liquid be between 50-86 °F, with a maximum kinematic viscosity of $1.6 \times 10^{-5} ft^2/s$ and a maximum density of 62.4 lb/ft^3. Based on these parameters, the specific gravity of the test liquid will be between 1.000 and 0.995 and, therefore, can be treated as unity when testing in accordance with the DOE test procedure.

As indicated in equation (8), the calculated shaft input power for the minimally compliant pump at each load point is then combined with a minimally compliant motor for that default motor type and appropriate size, as described in section III.D.1, and the default part load loss curve, as described in section III.D.2, to determine the input power to the motor at each load point. Id.

As noted previously, HI and CA IOUs expressed their support of DOE's proposed approach. (HI, No. 8 at p. 7; CA IOUs, NOPR public meeting transcript, No. 7 at p. 110) HI also pointed out in its written comments that $\eta_{pump,STD}$ incorrectly appeared twice in the middle term in the denominator in equation (10) of the April 2015 pumps test procedure NOPR. (HI, No. 8 at p. 15) DOE acknowledges the correction and has implemented the equation correctly in this final rule document. Having received no other comments, DOE is adopting the calculation procedure for PER_{STD} as proposed in the April 2015 pumps test procedure NOPR, with the minor clarifications regarding the number of digits reported for certain equation coefficients and calculation of specific speed for multi-stage pumps as noted above and correcting the erroneous terms that occurred in the April 2015 pump test procedure NOPR.

Regarding the calculation of pump hydraulic output power presented in equation (9), DOE notes that the equation presented in the April 2015 pumps test procedure NOPR specifies a denominator of 3956. 80 FR 17586, 17605 (April 1, 2015). DOE notes that this value represents the unit conversion from the product of flow (Q) in gpm, head in ft, and specific gravity (which is dimensionless), to horsepower. Conversely, DOE observes that HI 40.6–2014 specifies a value of 3960 in section 40.6.6.2 in regards to calculating pump efficiency. HI 40.6–2014 does not specify a specific unit conversion factor for the purposes of calculating pump hydraulic output power. Instead HI 40.6–2014 provides the following equation (10) for determining pump power output:

$$P_u = \rho \times Q \times H \times g \qquad \textbf{(10)}$$

Where:

P_u = the measured hydraulic output power of the tested pump,[43]

ρ = density,

Q = the volume rate of flow,

H = pump total head, and

g = acceleration due to gravity.

As shown in equation (10), the unit conversion factor can be derived from the product of density and acceleration due to gravity. An analysis was performed to convert from the metric units for density and acceleration due to gravity specified in HI 40.6–2014 to the appropriate units. This analysis found the value of 3956 to be more accurate and have a greater amount of precision than the 3960 value specified in HI 40.6–2014. DOE notes that, in its submitted comments, HI suggested a definition for hydraulic power as “the mechanical power transferred to the liquid as it passes through the pump, also

[43] For each of the quantities listed, HI 40.6–2014 provides multiple metric and U.S. customary units. Appendix E also provides unit conversions.

known as pump output power. (Refer to HI 40.6−2014)" and provided the following equation (11):

$$P_u = \frac{Q \times H \times SG}{3960} \quad \textbf{(11)}$$

Where:

P_u = measured hydraulic output power (hp),

Q = measured flow rate (gpm),

H = measured pump total head (ft), and

SG = the specific gravity of the test fluid.

(HI, No. 8 at p. 10; HI, No. 15 at p. 3)

However, as noted above, DOE believes a unit conversion of 3956 is more accurate. Therefore, to ensure consistent calculations and results in the DOE test procedure, in this final rule DOE is maintaining a unit conversion factor of 3956 instead of the 3960 value specified in HI 40.6–2014 and clarifying that the 3960 calculation in section 40.6.6.2 of HI 40.6–2014 should not be used. The calculation and rounding requirements for the pumps test procedure are described further in section III.C.2.f.

C. Determination of Pump Performance

To determine PEI_{CL} or PEI_{VL} for applicable pumps, DOE proposed that the test procedure would require physically measuring the performance of either: (1) the bare pump, under the calculation-based methods (see section III.E.1), or (2) the entire pump, inclusive of any motor, continuous control, or non-continuous control, under the testing-based methods (see section III.E.2). Specifically, the input power to the pump at 75, 100, and 110 percent of BEP flow for PEI_{CL}, or at 25, 50, 75, and 100 percent of BEP flow for PEI_{VL}, would be required for input into the PEI_{CL} or PEI_{VL} equations, respectively. DOE proposed that, depending on whether the calculation-based method or testing-based method were applied, a slightly different test method would apply for measuring pump performance. In the case of the calculation-based method, only the bare pump performance is physically measured—the performance of the motor and any continuous or non-continuous controls would be addressed through a series of calculations. In the case of the testing-based method, the input power to the pump at the motor or at the continuous or non-continuous control, if any, is directly measured and used to calculate PEI_{CL} or PEI_{VL}. 80 FR 17586, 17606-07 (April 1, 2015).

1. Incorporation by Reference of HI 40.6–2014

Regarding the determination of bare pump performance, the CIP Working Group recommended that whatever procedure DOE adopts, it should be consistent with HI 40.6–2014 for determining bare pump performance. (Docket No. EERE-2013-BT-NOC-0039, No. 92, Recommendation #10 at pg. 4) In preparation of the April 2015 pump test procedure NOPR, DOE reviewed HI 40.6–2014 and determined that it contains the relevant test methods needed to accurately characterize the performance of the pumps that would be addressed by this rulemaking, with a few minor modifications noted in section III.C.2. Specifically, HI 40.6–2014 defines and explains how to calculate pump power input,[44] driver power input (for testing-based methods),[45] pump power output,[46] pump efficiency,[47] bowl efficiency,[48] overall efficiency,[49] and other relevant quantities at the specified load points necessary to determine PEI_{CL} and PEI_{VL}. HI 40.6–2014 also contains appropriate specifications regarding the scope of pumps covered by the test methods, test methodology, standard rating conditions, equipment specifications, uncertainty calculations, and tolerances.

Accordingly, in the April 2015 pumps test procedure NOPR, DOE proposed to incorporate by reference HI 40.6–2014 as part of DOE's test procedure for measuring the energy consumption of pumps, with the minor modifications and exceptions listed in III.C.2.a through III.C.2.f of the NOPR document and discussed in more detail in section III.C.2 of this final rule. 80 FR 17586, 17607-12 (April 1, 2015).

HI commented that it agrees with using HI 40.6–2014 as the basis of DOE test procedure for pumps. (HI, No. 8 at p. 15) DOE received no other comments on this proposal in the April 2015 pumps test procedure NOPR and, therefore, is incorporating

---

[44] The term "pump power input" in HI 40.6–2014 is defined as "the power transmitted to the pump by its driver" and is synonymous with the term "pump shaft input power," as used in this document.

[45] The term "driver power input" in HI 40.6–2014 is defined as "the power absorbed by the pump driver" and is synonymous with the term "pump input power to the driver," as used in this document.

[46] The term "pump power output" in HI-40.6 is defined as "the mechanical power transferred to the liquid as it passes through the pump, also known as pump hydraulic power." It is used synonymously with "pump hydraulic power" in this document.

[47] The term "pump efficiency" is defined in HI 40.6–2014 as a ratio of pump power output to pump power input.

[48] The term "bowl efficiency" is defined in HI 40.6–2014 as a ratio of pump power output to bowl assembly power input and is applicable only to VTS and RSV pumps.

[49] The term "overall efficiency" is defined in HI 40.6–2014 as a ratio of pump power output to driver power input and describes the combined efficiency of a pump and driver.

by reference HI 40.6–2014 as the basis for the DOE pumps test procedure, with the minor modifications and exceptions listed in section III.C.2 of this final rule.

2. Minor Modifications and Additions to HI 40.6–2014

In general, DOE finds the test methods contained within HI 40.6–2014 are sufficiently specific and reasonably designed to produce test results that accurately measure the energy efficiency and energy use of applicable pumps. However, as proposed in the April 2015 pumps test procedure NOPR, DOE believes a few minor modifications are necessary to ensure repeatable and reproducible test results and to provide measurement methods and equipment specifications for the entire scope of pumps that DOE is addressing as part of this final rule. DOE's proposed modifications and clarifications to HI 40.6–2014, comments received on those topics, DOE's responses to those comments, and any changes to the April 2015 pumps test procedure NOPR proposals that DOE is making as a result are addressed in the subsequent sections III.C.2.a through III.C.2.f.

a. Sections Excluded from DOE's Incorporation by Reference

While DOE is referencing HI 40.6–2014 as the basis for its test procedure, in the April 2015 pumps test procedure NOPR, DOE noted that some sections of the standard are not applicable to DOE's regulatory framework. Specifically, DOE noted that section 40.6.5.3 provides requirements regarding the generation of a test report and appendix "B" provides guidance on test report formatting, both of which are not required for testing and rating pumps in accordance with DOE's procedure. In addition, DOE noted that section A.7 of appendix A, "Testing at temperatures exceeding 30 °C (86 °F)," HI 40.6–2014 addresses testing at temperatures above 30 °C (86 °F), which is inconsistent with DOE's proposal to only test with liquids meeting the definition of "clear water" established in section 40.6.5.5 of HI 40.6–2014. As such, DOE proposed not incorporating by reference section 40.6.5.3, section A.7, and appendix B of HI 40.6–2014. 80 FR 17586, 17608 (April 1, 2015).

HI commented that it agrees with the proposal to not incorporate by reference section 40.6.5.3, section A.7, and appendix B of HI 40.6–2014 as part of the DOE test procedure. (HI, No. 8 at 15) DOE received no other comments on this proposal in the April 2015 pumps test procedure NOPR and, as such, is adopting the proposal in the April 2015 pumps test procedure NOPR to incorporate by reference HI 40.6–2014 except for section 40.6.5.3, section A.7, and appendix B in this final rule.

In reviewing the relevant sections of HI 40.6−2014, DOE also noted that section 40.6.4.1, "Vertically suspended pumps," which contains specific testing instructions for vertically suspended VS1 and VS3 pumps, mentions VS0 pumps. Specifically, section 40.6.4.1 states "A variation to this is pump type VS0…[a] VS0 [pump] is evaluated as a pump end only similar to the bowl performance and efficiency described for the line-shafted product." DOE notes that this language in HI 40.6−2014 is intended to exclude VS0 pumps from the specifications in section 40.6.4.1 and specify that testing for VS0, as a type of vertical turbine pump, must consider only bowl assembly total head and, for VTS bare pumps, only the bowl assembly power input, as defined in section 40.6.2 of HI 40.6−2014. However, DOE believes that the language of section 40.6.4.1 is somewhat confusing and may lead to misinterpretation by some not familiar with all the varieties of vertical turbine and vertically suspended pumps and their specific testing considerations. Therefore, in this final rule, DOE is clarifying that the specifications of section 40.6.4.1 of HI 40.6–2014 do not apply to VTS pumps and that the performance of VTS bare pumps considers the bowl performance only. For VTS pumps sold with motors evaluated using the testing-based approaches discussed in section III.E.2, the bowl assembly total head and driver power input are to be used to determine the pump performance.

b. Data Collection and Determination of Stabilization

In order to ensure the repeatability of test data and results, the DOE pump test procedure must provide instructions regarding how to sample and collect data at each load point such that the collected data are taken at stabilized conditions that accurately and precisely represent the performance of the pump at that load point. Section 40.6.5.5.1 of HI 40.6–2014 provides that all measurements shall be made under steady state conditions, which are described as follows: (1) no vortexing, (2) margins as specified in ANSI/HI 9.6.1 Rotodynamic Pumps Guideline for NPSH Margin, and (3) when the mean value of all measured quantities required for the test data point remains constant within the permissible amplitudes of fluctuations defined in Table 40.6.3.2.2 over a minimum period of 10 seconds before performance data are collected. HI 40.6–2014 does not specify the measurement interval for determination of steady state operation. However, DOE understands that a minimum of two stabilization measurements are required to calculate an average. DOE proposed in the April 2015 pumps test procedure NOPR that the stabilization measurement interval should not be greater than 5 seconds, thereby allowing for no fewer than two separate measurements that each have an integration time of no more than 5 seconds. 80 FR 17586, 17606 (April 1, 2015).

Section 40.6.3.2.2 of HI 40.6–2014, “Permissible fluctuations,” also provides that permissible damping devices may be used to minimize noise and large fluctuations in the data in order to achieve the specifications noted in Table 40.6.3.2.2. In the April 2015 pumps test procedure NOPR, DOE proposed to specify that damping devices would only be permitted to integrate up to the measurement interval to ensure that each stabilization data point is reflective of a separate measurement. 80 FR 17586, 17606 (April 1, 2015).

DOE requested comment on its proposal to require that data be collected at least every 5 seconds for all measured quantities. HI commented that collecting stabilization data every 5 seconds is not standard industry practice, and that this practice would require manufacturers to obtain automated data acquisition systems, posing additional and unnecessary burden not agreed to by the CIP Working Group. (HI, No. 8 at pp. 15–16) HI recommended that steady-state operation be verified by recording flow at the beginning and end of the data acquisition and checking that the difference in flow is within the allowable fluctuation identified in HI 40.6–2014 (Table 40.6.3.2.2). HI also stated that the two flow readings should be separated by a minimum of 5 seconds.

DOE also requested comment on its proposal to allow damping devices, as described in section 40.6.3.2.2, but with integration limited to the data collection interval and HI commented that it agrees with this proposal except with respect to the interval used for data collection. (HI, No. 8 at p. 16)

After reviewing HI's comments and considering the proposal in the April 2015 pump test procedure NOPR, DOE maintains that at least two unique measurements, at a minimum, are necessary to determine stabilization prior to recording a measurement at a given load point. DOE also agrees with HI that it is appropriate to continue to reference the requirements for permissible fluctuations and minimum duration of stabilization testing, as detailed in HI 40.6–2014 sections 40.6.3.2.2 and 40.6.5.5.1. However, in light of HI's concern regarding automated data collection requirements if the interval of data collection is specified as 5 seconds, DOE has determined that a threshold for the data collection interval does not need to be specified to determine steady state operation provided the other requirements for stabilization are satisfied. That is, provided that at least two unique measurements are recorded, their mean computed, and that the two unique measurements are not farther away from the mean than the tolerance specified in the "permissible amplitude of fluctuation" table (Table 40.6.3.2.2) in HI 40.6–2014, the pump can be determined to be stabilized and data recorded for the purposes of conducting the DOE test procedure. DOE notes that section 40.6.5.5.1 requires that steady state be determined for a minimum of 10 seconds, but that a longer time can be used if necessary, in which case the two unique measurements could be recorded more than 5 seconds apart. For example, if a facility were not equipped with a data acquisition system, stabilization could be determined over 1 minute and data taken every 30 seconds to determine stabilized operation at each flow point.

Regarding the use of damping devices, DOE is maintaining the requirements that the integration time for each measurement cannot be greater than the measurement interval. This is necessary to ensure that the measurements used to determine stabilization are, in fact, unique. Therefore, in this test procedure final rule, DOE is adopting stabilization requirements consistent with HI section 40.6.3.2.2 and section 40.6.5.5.1, except that at least two unique measurements must be used to determine stabilization and any damping devices are only permitted to integrate up to the data collection interval. DOE notes that, for physical dampening devices, the pressure indicator/signal must register 99 percent of a sudden change in pressure over the measurement interval to satisfy the requirement for unique measurements, consistent with annex D of ISO 3966:2008(E), "Measurement of fluid flow in closed conduits – Velocity area method using Pitot static tubes," which is referenced in HI 40.6 -2014 for measuring flow with pitot tubes.

c. Modifications Regarding Test Consistency and Repeatability

Sections 40.6.5.6 and 40.6.5.7 of HI 40.6–2014 specify test arrangements and test conditions. However, DOE finds that the standardized test conditions described in these sections are not sufficient to produce accurate and repeatable test results. To address these potential sources of variability or ambiguity, in the April 2015 pumps test procedure NOPR, DOE proposed to adopt several additional requirements regarding the nominal pump speed, the input power characteristics, and the number of stages to test for multi-stage pumps to further specify the procedures for testing pumps in a standardized and repeatable manner. 80 FR 17586, 17608 (April 1, 2015).

Pump Speed

The rotating speed of a pump affects the efficiency and PEI_{CL} or PEI_{VL} of that pump. To limit variability and increase repeatability within the test procedure, DOE proposed in the April 2015 pumps test procedure NOPR to require all test data to be normalized to one of two nominal speeds—1,800 or 3,600 rpm at 60 Hz. Specifically, pumps designed to operate at any speed of rotation between 2,880 and 4,320 rpm would be rated at 3,600 rpm, and pumps designed to operate at any speed of rotation between 1,440 and 2,160 rpm would be rated at 1,800 rpm, as noted in Table III.3. 80 FR 17586, 17609 (April 1, 2015).

Table III.3 Nominal Speed of Rotation for Different Configurations of Pumps

Pump Configuration	Pump Design Speed of Rotation	Style of Motor	Nominal Speed of Rotation for Rating
Bare Pump	2,880 and 4,320 rpm	N/A	3,600 rpm
	1,440 and 2,160 rpm		1,800 rpm
Pump + Motor OR Pump + Motor + Control	N/A	2-pole Induction Motor	3,600 rpm
	N/A	4-pole Induction Motor	1,800 rpm
	N/A	Non-Induction Motor Designed to Operate between 2,880 and 4,320 rpm	3,600 rpm
	N/A	Non-Induction Motor Designed to Operate between 1,440 and 2,160 rpm	1,800 rpm

DOE proposed that, for pumps sold without motors, the nominal speed would be selected based on the speed of rotation for which the pump is designed to be operated, while for pumps sold with motors, the nominal speed of rotation would be selected based on the speed(s) for which the motor is designed to operate. DOE also clarified that pumps designed to operate at speeds that include both ranges would be rated at both nominal speeds of rotations since each nominal speed rating represents a different basic model of pump. Finally, DOE noted that these speed ranges are not exclusive. That is, if a pump were to be designed to operate from 2,600 to 4,000 rpm, such a pump would have a nominal speed of rotation of 3,600 rpm for the purposes of testing and rating the pump, even though part of the operating range of the pump (i.e., 2,600 to 2,880 rpm) falls outside DOE's specified speed ranges.

In DOE's April 2015 pumps test procedure NOPR proposal, DOE acknowledged that it may not be feasible to operate pumps during the test at exactly the nominal speeds of 3,600 or 1,800 rpm and noted that section 40.6.5.5.2 of HI 40.6–2014 allows for tested speeds up to 20 percent off of the nominal speed, provided the tested speed does not vary more than ±1 percent at each load point as required by section 40.6.3.2.2 of HI 40.6–2014. However, to ensure consistent and comparable test results, DOE proposed that all data collected during the test procedure at the speed measured during the test should be adjusted to the nominal speed prior to use in subsequent calculations and the PEI_{CL} or PEI_{VL} of a given pump should be based on the nominal speed. Id. For pumps sold with motors and continuous or non-continuous controls and that are tested using the testing-based method described in section III.E.2.c, DOE proposed that this adjustment to the nominal speed only apply at the 100 percent of BEP flow load point and that subsequent part load points be measured at reduced speed and used in subsequent calculations without adjustment. DOE also proposed to use the methods in HI 40.6–2014 section 40.6.6.1.1, "Translation of the test results into data based on the specified speed of rotation (for frequency) and density" to adjust any data from the tested speed to the nominal speed. Id.

DOE requested comment on its proposal to require data collected at the pump speed measured during testing to be normalized to the nominal speeds of 1,800 and 3,600 rpm. HI commented that it agrees with the proposal. (HI, No. 8 at p. 16)

Therefore, in this test procedure final rule, DOE is opting to adopt the operating speed limits proposed in the April 2015 pumps test procedure NOPR and discussed in section III.A.4 for the purposes of applying this test procedure final rule.

DOE also requested comment on its proposal to adopt the requirements in HI 40.6–2014 regarding the deviation of tested speed from nominal speed and the variation of speed during the test, specifically regarding whether maintaining tested speed within ±1 percent of the nominal speed is feasible and whether this approach would produce more accurate and repeatable test results. HI commented that it does not believe it is feasible to maintain tested speed within ±1 percent of the specified nominal speed because typical motor speed-load curves do not meet this criterion. (HI, No. 8 at p. 16) However, HI also noted that data could be collected and rotating speed maintained at ±1 percent for a particular data collection point. DOE believes that HI may have misinterpreted the proposal in the April 2015 pumps test procedure NOPR. In the NOPR, DOE proposed maintaining the speed of rotation at each test point within the ±1 percent speed tolerance, but that the speed of rotation at each test point could vary from the nominal speed of rotation ±20 percent, consistent with HI 40.6−2014. DOE agrees that the ±1 percent speed tolerance is applicable to determining stabilization at each data collection point only and is not determined relative to nominal speed and, therefore, is adopting the April 2015 pump test procedure NOPR proposal to adopt the nominal speed tolerances listed in section 40.6.5.5.2 of HI 40.6–2014, as well as the stabilization requirements provided in section 40.6.3.2.2 of HI 40.6–2014 in this test procedure final rule. Additionally, DOE is adopting the provisions that all measured data be translated to the nominal rating speed.

Power Supply Characteristics

Because pump power consumption is a component of the proposed metric, inclusive of any motor and continuous or non-continuous controls, measuring power consumption is an important element of the test. The characteristics of the power supplied to the pump affect the accuracy and repeatability of the measured power consumption of the pump. As such, to ensure accurate and repeatable measurement of power consumption, in the April 2015 pumps test procedure NOPR, DOE specified nominal values for voltage, frequency, voltage unbalance, total harmonic distortion (THD), and impedance levels, as well as tolerances about each of these quantities, that must be maintained at the input terminals to the motor, continuous control, or non-continuous control, as applicable when performing the testing-based methods or when using a calibrated motor to determine bare pump performance. 80 FR 17586, 17610 (April 1, 2015).

To determine the appropriate power supply characteristics for testing pumps with motors (but without continuous or non-continuous controls) and pumps with both motors and continuous or non-continuous controls, DOE examined applicable test methods for electric motors and VSD systems. DOE determined that the Institute of Electrical and Electronics Engineers (IEEE) Standard 112-2004, "IEEE Standard Test Procedure for Polyphase Induction Motors and Generators," (IEEE 112-2004) and the Canadian Standards Association (CSA) C390-10, "Test methods, marking requirements, and energy efficiency levels for three-phase induction motors," (CSA C390-10) are the most relevant test methods for measuring input power to electric motors, as they are the test methods incorporated by reference as the DOE test procedure for electric motors. Other widely referenced industry standard test methods for motors include: IEC 60034-1 Edition 12.0 2010-02, "Rotating electrical machines - Part 1: Rating and performance" (IEC 60034-1:2010) and NEMA MG 1–2014, "Motors and Generators" (NEMA MG 1-2014). DOE also identified both AHRI 1210–2011, "2011 Standard for Performance Rating of Variable Frequency Drives," (AHRI 1210–2011) and the 2013 version of CSA Standard C838, "Energy efficiency test methods for three-phase variable frequency drive systems," (CSA C838–13) as applicable methods for measuring the performance of VSD control systems. A summary of DOE's proposed power supply characteristics and the requirements of the industry standards DOE referenced in developing such a proposal are summarized in Table III.4.

Table III.4 Summary of Tolerances Proposed by DOE in the April 2015 Pumps Test Procedure NOPR and Referenced in Relevant Industry Standards.

Reference Document	Section	Voltage Unbalance	Voltage Tolerance	Frequency Tolerance	Voltage Waveform Distortion	Source Impedance
April 2015 Pumps Test Procedure NOPR Proposal	III.C.2.c	± 0.5%	± 0.5%	± 0.5%	THD ≤ 5%	
HI 40.6–2014 (calibrated motors)	C.4.1		± 5%	± 1%		

Reference Document	Section	Voltage Unbalance	Voltage Tolerance	Frequency Tolerance	Voltage Waveform Distortion	Source Impedance
CSA C390-10 (motors)	5.2	± 0.5%	± 0.5%	± 0.5%	THD ≤ 5% (to 20th)	
IEC 60034-1:2010 (motors)	7.3		± 5%* (zone A)	± 2%* (zone A)		
	9.11				THD ≤ 5% (to 100th)	
IEEE 112-2004 (motors)	3.1	≤ 0.5%		± 0.5%	THD ≤ 5%	
NEMA MG 1-2014 (motors)	7.7.3.2	≤ 1%		± 0.5%	deviation factor ≤ 10%	
	12.44.1		± 10%**	± 5%**		
	12.45	≤ 1%†				
AHRI 1210-2011 (VFDs)	5.1.2	≤ 0.5%	± 0.5%	± 0.5%		≤ 1%
CSA C838-13 (VFDs)	5.3	± 0.5%	± 0.5%	± 0.5%	THD ≤ 5% (to 20th)	1% < value ≤ 3% of VFD

* Values are for the overall bounds of the hexagonal surface in IEC Figure 12.
** NEMA states that performance within these voltage and frequency variations will not necessarily be in accordance with the standards established for operation at rated voltage and frequency.
† NEMA states that performance will not necessarily be the same as when the motor is operating with a balanced voltage at the motor terminals.

HI commented that it disagrees with the power conditioning requirements proposed in the April 2015 pumps test procedure NOPR; knows of no pump test labs that meet them; and views them as a significant and unnecessary burden to manufacturers that were not agreed to by the CIP Working Group. HI specifically cited costs associated with the proposed limitation on voltage unbalance, and noted that the nominal motor efficiency values used for the calculation method have a less stringent tolerance of 2 percent. HI also indicated that testing with unconditioned power will result in a lower efficiency value and a higher PEI value than when testing with conditioned power. HI proposed that whereas conditioned power, as proposed in the April 2015 pumps test procedure NOPR, should be used for DOE enforcement testing and motor calibration, manufacturer test labs should only be held to the 3 percent limit for driver input power fluctuation specified in HI 40.6–2014. (HI, No. 8 at pp. 16–18)

Regal Beloit stated during the April 2015 NOPR public meeting that motor manufacturers faced similar challenges when motor standards were introduced, and third-party test labs adapted to help meet the power conditioning requirements. Regal Beloit also indicated that AHRI 1210 was not developed for pumps, and CSA C838 would be preferred. In addition, Regal Beloit expressed concern that any loosening of the power conditioning requirements could hinder differentiation between lower and higher performing products. (Regal Beloit, NOPR public meeting transcript, No. 7 at pp. 137–46)

As noted in the April 2015 pumps test procedure NOPR, DOE recognizes that driver efficiency can vary: (a) when the input voltage level is not exactly at the nameplate voltage, (b) when the fundamental frequency of the input voltage waveform is not exactly 60 Hz, (c) when input voltage phases are unbalanced, and/or (d) when the input voltage waveform is not strictly sinusoidal. However, DOE acknowledges the concerns of HI regarding the burden of providing power meeting strict voltage, frequency, voltage unbalance, and THD limits. As EPCA requires DOE test procedures to not be unduly burdensome to conduct (42 U.S.C. 6314(a)(2)), DOE, in this final rule, is reconsidering the proposed requirements regarding the power supply characteristics to find a compromise among repeatability, accuracy, and test burden.

DOE notes that HI's proposal of a ±3 percent tolerance on power is not feasible without some parameters around power supply characteristics, as variation in voltage unbalance, harmonics, voltage, and frequency will affect the variability in the measurement of input power to the pump insofar as it will affect the performance and efficiency of the motor. That is, for example, increased voltage unbalance will affect motor performance such that testing the same pump sold with a motor under differing voltage unbalance conditions will result in different measured pump performance. This can be viewed either as: (1) different (typically lower) hydraulic output for the same input power to the motor or (2) different (typically increased) input power to the motor to deliver the same hydraulic output power.

Under the latter scenario, DOE has developed an approach to correlate variability in power supply characteristics with variability in the measured input power to the motor. Similarly, DOE separately considered how variability in power supply characteristics would impact input power to the continuous or non-continuous controls. Specifically, DOE determined, for each power supply characteristic (i.e., voltage, frequency, voltage unbalance, and voltage THD) the level of variability that was associated with HI's proposed acceptable tolerance of ±3 percent on driver input power. As such, DOE considered each of the power supply variables individually to determine if alternative, less burdensome requirements were feasible.

Regarding the impact of variation in voltage, section 12.44.1 of NEMA MG 1-2014 specifies that AC motors shall operate successfully under running conditions at rated load with a variation in the voltage up to ±10 percent of rated (nameplate) voltage with rated frequency for induction motors. Similarly, according to Figure 5-1 in the DOE

Advanced Manufacturing Office (AMO) "Premium Efficiency Motor Selection and Application Guide" (AMO motor handbook), the efficiency of a "pre-EPAct"[50] standard efficiency motor varies by less than ±3 percent when operated at ±10 percent of nameplate voltage. Section 2.2.2 of ANSI C84.1-2011 states that the nominal voltage of a system is near the voltage level at which the system normally operates, and that systems generally operate at voltage levels about 5 to 10 percent below the maximum system voltage for which system components are designed. DOE also notes that section C.4.1 of HI 40.6-2014 indicates that when a calibrated motor is used to determine the pump input power, the voltage shall be the same as used during the calibration of the motor with a tolerance of ±5 percent; this specification is consistent with the ±5 percent outermost limits in Figure 12 of IEC 60034-1:2010 for zone A (continuous operation). In consideration of these standards, DOE has determined that, within reasonable limits, motor performance does not appear to be strongly affected by variation in voltage. However, DOE believes that it is important to ensure voltage is maintained within those reasonable limits. Therefore, in this final rule, DOE is adopting a tolerance on voltage consistent with the requirements in HI 40.6–2014 of ± 5.0 percent of the nominal rated voltage. DOE believes such a proposal provides representative measurements without imposing undue test burden on manufacturers.

Considering the impact of frequency on the rated performance of pumps and motors, the AMO motor handbook states that a premium efficiency motor is usually 0.5 to 2.0 percent more efficient when operating at 60 Hz than when the same motor is driven

[50] Energy Policy Act of 2005, Pub. L. 109-58, 119 Stat. 594

by a 50-Hz power supply, suggesting that motor performance is not strongly dependent on frequency. However, section C.4.1 of HI 40.6-2014 indicates that when a calibrated motor is used to determine the pump input power, the frequency shall be the same as used during the calibration of the motor with a tolerance of ±1 percent. DOE believes that the HI requirement would be equally applicable to determining the performance of pumps sold with motors and pumps sold with motors and continuous or non-continuous controls under the testing-based methods to ensure repeatable and accurate measurements. Therefore, in this final rule, DOE is relaxing the proposal in the April 2015 pumps test procedure NOPR to instead limit frequency variation of ±1.0 percent of nameplate frequency, consistent with HI 40.6–2014. DOE also notes that the U.S. electric grid typically provides power at a frequency within these bounds and, as such, DOE believe such a tolerance will not impose undue test burden. Further, DOE believes that maintaining tolerances consistent with the typical U.S. electric power supply is necessary to ensure repeatability of the test and ensure that the test is representative of the energy consumption of the equipment. Specifically, a specification of ±1 percent is consistent with the ±1 percent tolerance for continuous operation across all durations of off-nominal frequency specified in the North American Electric Reliability Corporation (NERC) Standard PRC-024-1, "Generator Frequency and Voltage Protective Relay Settings."

Regarding voltage unbalance, DOE notes that motor performance will vary as a function of voltage unbalance. Specifically, NEMA MG 1-2014 includes a horsepower derating curve for up to 5 percent voltage unbalance and recommends limiting voltage unbalance to 1 percent, noting that motor performance will not necessarily be the same as when the motor is operating with a balanced voltage at the motor terminals. Similarly, Table 5-3 in the AMO motor handbook relates a voltage unbalance of 3 percent to a decrease in motor efficiency of 2 to 3 percent, compared with a decrease of 5 percent or more for a voltage unbalance of 5 percent.[51] DOE notes that a variation of 3 percent in motor efficiency equates to a 3 percent variability in measured input power to the motor.

Given the dependence of motor, and thus pump, performance on voltage unbalance, DOE then evaluated the relative burden associated with providing different levels of voltage unbalance in the test facility, in an effort to determine a level of voltage unbalance that would not be unduly burdensome to specify in the test procedure. DOE researched typical levels of voltage unbalance available on the national electric grid, based on utility standards and specifications for generation and distribution of power. NEMA MG 1-2014 states that if a motor is subjected to more than 1 percent voltage unbalance the manufacturer should be consulted regarding this unusual service condition, and the AMO motor handbook states that unbalances exceeding 1 percent will void most manufacturers' warranties. DOE also found that PG&E Electric Rule No. 2 states that the voltage balance between phases for service delivery voltages will be maintained by PG&E as close as practicable to 2.5 percent.[52] Similarly, Annex C of ANSI C84.1-2011 indicates that approximately 98 percent of the electric supply systems surveyed were found to be below 3.0 percent voltage unbalance, and 66 percent were found to be below

[51] DOE Office of Energy Efficiency and Renewable Energy (EERE), Premium Efficiency Motor Selection and Application Guide—A Handbook for Industry (February 2014, www.energy.gov/eere/amo/motor-systems).
[52] Accessed on August 21, 2015, at www.pge.com/tariffs/tm2/pdf/ELEC_RULES_2.pdf.

1.0 percent; the standard states that electric supply systems should be designed and operated to limit the maximum voltage unbalance to 3 percent when measured at the electric-utility revenue meter under no-load conditions.[53] Therefore, DOE determines 3.0 percent voltage unbalance provides a reasonable tolerance, would be generally available to most testing facilities using grid-supplied power and would limit the impact on input power to less than 3 percent, consistent with HI's recommendation.

Regarding limitations on harmonic distortion on the power supply, the AMO publication, "Improving Motor and Drive System Performance" (AMO motor sourcebook) states that electrical equipment is often rated to handle 5 percent THD (as defined in IEEE Std 519), and notes that motors are typically much less sensitive to harmonics than computers or communication systems.[54] Similarly, IEC 60034-1:2010 specifies a limit of 5 percent voltage THD, measured to the 100th harmonic. In addition, for bus voltage of 1.0 kV or less at the point of common coupling (PCC), section 5.1 of IEEE Std 519-2014 recommends line-to-neutral harmonic voltage limits of 5.0 percent individual harmonic distortion and 8.0 percent voltage THD for weekly 95th percentile short time (10 min) values, measured to the 50th harmonic. The IEEE standard also indicates that daily 99th percentile very short time (3 second) values should be less than 1.5 times these values. NEMA MG 1-2014 uses different metrics (voltage waveform deviation factor and harmonic voltage factor or HVF) to establish harmonic voltage limits and horsepower derating factors for motors. However, the NEMA metrics are not

[53] American National Standard For Electric Power Systems and Equipment—Voltage Ratings (60 Hertz).
[54] DOE EERE, Improving Motor and Drive System Performance—A Sourcebook for Industry (February 2014, www.energy.gov/eere/amo/motor-systems).

directly comparable to voltage THD, and the HVF derating curve was developed under the assumption that any voltage unbalance or even harmonics are negligible.[55] In consideration of these recommendations regarding voltage THD limits and potentially significant impacts on motor performance, in this final rule, DOE is limiting voltage THD to ≤12.0 percent (corresponding to the IEEE 3-second limit but measured to the 40th harmonic) in this final rule to ensure representative and repeatable measurements. DOE also notes that a limit of ≤12.0 percent voltage THD is not unduly burdensome for test labs as it is within the bounds of standardized voltage THD limits placed on grid operators and, thus, is generally available on the national electric power grid.

DOE also discussed source impedance in the NOPR and considered adopting specifications in AHRI 1210-2011 (source impedance ≤1 percent) or CSA C838-13 (source impedance > 1.0 percent of VFD and ≤ 3.0 percent of VFD) for motors and speed controls. 80 FR 17586, 17611-12 (April 1, 2015). DOE understands that a nonlinear load can distort the voltage waveform, depending on the magnitudes of the source impedance and current distortion.[56] However, DOE also understands that motors are not a significant source of harmonics in the current waveform if the steel core is not

---

[55] NEMA's voltage deviation factor is calculated as the maximum difference between corresponding ordinates of the voltage waveform and of the equivalent sine wave, divided by the maximum ordinate of the equivalent sine wave when the waves are superimposed such that the maximum difference is minimized. Harmonic voltage factor (HVF) is calculated by squaring the ratio of harmonic voltage to rated voltage for each odd harmonic not divisible by three (up to some specified order, e.g., the 13th harmonic in IEC 60034-1:2010), dividing each result by the order of the corresponding harmonic, and then taking the square root of the sum of these quotients. Voltage THD is calculated by taking the square root of the sum of squares of each RMS harmonic voltage (up to some specified order, e.g., the 50th harmonic in IEEE 519-2014), and then dividing by the RMS fundamental voltage.

[56] IEEE Std 1560-2005, "IEEE Standard for Methods of Measurement of Radio-Frequency Power-Line Interference Filter in the Range of 100 Hz to 10 GHz" (February 2006).

magnetically saturated,[57] and that motor efficiency is not greatly affected by harmonics in the voltage waveform if voltage THD is sufficiently limited. Therefore, in this final rule, DOE is not specifying source impedance requirements. DOE believes that the adopted requirements for the preceding four power supply characteristics (i.e., voltage unbalance, voltage, frequency, and voltage THD) will sufficiently limit variability in motor performance resulting from variations in the characteristics of the mains power supplied to the motor.

Regarding the impact of variation in power supply characteristics on continuous and non-continuous controls, DOE understands that motors, continuous controls, and non-continuous controls all have similar power conditioning requirements because they will be subjected to similar electrical conditions in the field. That is, based on DOE's research, manufacturers appear to have designed motors to be reasonably tolerant of variability in power supply characteristics (or power quality) that are characteristic of typical grid operation, but their performance is significantly impacted at levels outside the bounds of that commonly experienced in their field. While less information is available of the response of continuous and non-continuous controls to these power supply variables, DOE expects this relationship to be true for such controls as well. For example, NEMA guidance published in 2007 states that adjustable frequency controls can

[57] Fire Protection Research Foundation, "Evaluation of the Impact on Non-Linear Power On Wiring Requirements for Commercial Buildings" (June 2011, www.nfpa.org/research/fire-protection-research-foundation/projects-reports-and-proceedings/electrical-safety/new-technologies-and-electrical-safety/evaluation-of-the-impact-on-non-linear-power).

operate on power systems with a voltage unbalance not exceeding 3 percent.[58] In addition, guidance published by the Electric Power Research Institute (EPRI) in 2001 indicates that VSDs should be specified to operate without any problem for a voltage unbalance of 2 percent.[59] Consequently, DOE is applying, in this final rule, the same power conditioning requirements to pumps tested with motors and pumps tested with motors and continuous or non-continuous controls.

DOE notes that these requirements are applicable to pumps sold with motors and pumps sold with motors and continuous or non-continuous controls rated using the testing-based method, as such methods require measurement of electrical input power to the motor or control. Commensurately, these requirements are applicable to any pumps rated using a calculation-based method, including bare pumps, pumps sold with applicable electric motors, and pumps sold with applicable electric motors and continuous controls, when the bare pump is tested using a calibrated motor to determine pump shaft input power. Pumps evaluated based on the calculation method where the input power to the motor is determined using equipment other than a calibrated motor would not have to meet these requirements, as variations in voltage, frequency, voltage unbalance, and voltage THD are not expected to significantly affect the tested pump's energy performance.

---

[58] NEMA Application Guide for AC Adjustable Speed Drive Systems (December 2007, www.nema.org/Standards/Pages/Application-Guide-for-AC-Adjustable-Speed-Drive-Systems.aspx).
[59] EPRI Guide to the Industrial Application of Motors and Variable-Speed Drives (September 2001, www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001005983).

Number of Stages for Multi-Stage Pumps

RSV and VTS pumps are typically multi-stage pumps that may be offered in a variety of stages.[60] The energy consumption characteristics of such multi-stage pumps vary, approximately linearly, as a function of the number of stages. However, to simplify certification requirements and limit testing burden, DOE proposed in the April 2015 pumps test procedure NOPR that certification of RSV and VTS pumps be based on testing with the following number of stages:

- RSV: 3 stages; and
- VTS: 9 stages.

If a model is not available with that specific number of stages, the model would be tested with the next closest number of stages distributed in commerce by the manufacturer, or the next higher number of stages if both the next lower and next higher number of stages are equivalently close to the required number of stages. This is consistent with DOE's proposal, discussed previously in section III.A.1.c, that variation in number of stages for RSV and VTS pumps would not be a characteristic that constitutes different basic models. 80 FR 17586, 17610 (April 1, 2015).

In response to DOE's proposal regarding testing of multi-stage RSV and VTS pumps, HI commented that it agrees with this proposal. (HI, No. 8 at p. 18) DOE received no other comments on this proposal and has, therefore, adopted the provisions

[60] The stages of VTS pumps are also commonly referred to as "bowls." See section 2.1.3.1 and Figure 2.1.3.1 of ANSI/HI 2.1-2.2–2014.

for testing multi-stage RSV and VTS pumps proposed in the April 2015 pumps test procedure NOPR with no modifications.

Twin Head Pumps

A twin head pump is a type of IL pump that contains two impeller assemblies, mounted in two volutes that share a single inlet and discharge in a common casing. In response to the April 2015 pumps test procedure NOPR, DOE received comment from HI recommending that DOE include twin head pumps in this rulemaking and align their test procedure with Europump guidelines.[61] (HI, No. 8 at p. 3) These guidelines recommend testing a twin head pump by incorporating one of the impeller assemblies into an adequate IL type pump casing.

DOE agrees with HI's recommendation and, as discussed in section III.A.2.a, originally intended to include these pumps as a category of IL pumps. To clarify DOE's original intent in this final rule, DOE is adopting a definition of twin head pump, specifying that twin head pumps are a subset of the IL pump equipment category, and modifying the test procedure in this final rule to be consistent with the EU guidelines. DOE's definition for twin head pump and the modified IL definition are presented in section III.A.2.a. However, DOE also acknowledges that clarifications to the test procedure proposed in the April 2015 pumps test procedure NOPR are necessary to explicitly specify the procedures for testing twin head pumps in accordance with the

[61] Guideline on the application of COMMISSION REGULATION (EU) No 547/2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for water pumps (12th of September 2012)).

DOE test procedure. As such, DOE is establishing explicit instructions for configuring twin head pumps in this final rule.

In general, twin head pumps, as a subset of IL pumps, are tested in accordance with the test procedure for IL pumps. Specifically, twin head pumps, which are essentially two IL pumps packaged together in a single casing, are to be tested using an equivalent single-head IL configuration. That is, to test a twin head pump, one of the two impeller assemblies is to be incorporated into an adequate, IL style, single impeller volute and casing. An adequate, IL style, single impeller volute and casing means a volute and casing for which any physical and functional characteristics that affect energy consumption and energy efficiency are essentially identical to their corresponding characteristics for a single impeller in the twin head pump volute and casing.

d. Determination of Pump Shaft Input Power at Specified Flow Rates

HI 40.6–2014 provides a specific procedure for determining BEP for a given pump based on seven load points at 40, 60, 75, 90, 100, 110 and 120 percent of the expected BEP flow of the pump. The test protocol in section 40.6.6.2 of HI 40.6–2014 requires that the hydraulic power and the pump shaft input power, or input power to the motor for pumps tested using the testing-based methods, be measured at each of the seven load points. HI 40.6–2014 further specifies that the pump efficiency be determined as the hydraulic power divided by the shaft input power, or as the hydraulic power divided by the product of the measured input power to the motor and the known efficiency of a calibrated motor, depending on how the pump is tested. The equations for calculating pump efficiency are shown in equation (12):

$$\eta_{pump,i} = \frac{P_{Hydrou,i}}{P_i} = \frac{P_{Hydrou,i}}{P_i^{in,m} \times \eta_{motor,i}}$$

(12)

Where:

$\eta_{pump,i}$ = pump efficiency at load point i (%);

$P_{u,i}$ = pump hydraulic output power at load point i (hp);

P_i = pump shaft input power at load point i (hp);

$P_i^{in,m}$ = measured driver power input to the calibrated motor at load point i (hp);

$\eta_{motor,i}$ = the calibrated motor efficiency[62] at load point i (%); and

i = load point corresponding to 40, 60, 75, 90, 100, 110 or 120 percent of expected BEP flow.

The pump efficiency at each of these load points is then used to determine the tested BEP for a given pump and, in particular, the flow rate associated with the BEP of the pump (i.e., BEP flow). Then, based on the determined BEP flow, the pump shaft input power or input power to the motor is determined at each of the specified load points, as discussed in section III.B.

In the April 2015 pumps test procedure NOPR, DOE observed that the specific load points measured in the test protocol may not be exactly at 75, 100, or 110 percent of the BEP flow load points specified in the test procedure and, thus, the relevant power

[62] Note: to determine pump shaft input power based on the measured driver input power, a calibrated motor and the calibrated motor efficiencies at each load point i must be used where they are known with "sufficient accuracy," meaning that the efficiency of the motor combined with the power measurement device uncertainty must not exceed ±2.5 percent, as required by Table 40.6.3.2.3 in HI 40.6−2014.

input measurements—specifically, pump shaft input power, input power to the pump at the driver, or input power to the continuous or non-continuous controls—must be adjusted to reflect the power input at the specific load points specified in the test procedure. To adjust the measured power input values, DOE proposed that the measured input power and flow data corresponding to the load point from 60 percent of expected BEP flow to 120 percent of expected BEP flow be linearly regressed and the input power at the specific load point of 75, 100, and 110 percent of BEP flow be determined from that regression equation. 80 FR 17586, 17610-11 (April 1, 2015).

In response to the April 2015 pumps test procedure NOPR, HI commented that it agrees with DOE's proposal to use a linear regression of the pump input power with respect to flow rate at all the tested load points greater than or equal to 60 percent of expected BEP flow to determine the pump shaft input power at the specified load points of 75, 100, and 110 percent of BEP flow. (HI, No. 8 at p. 18) DOE received no other comments on the proposal and, as such, is adopting it as proposed in the April 2015 pump test procedure NOPR with no revisions or modifications.

Determination of Pump Shaft Input Power for Pumps with BEP at the Maximum Allowable Flow

HI 40.6–2014 contains a method for determining the BEP of tested pumps based on the flow rate at which the maximum pump efficiency occurs. DOE recognizes that there may be some unique pump models that do not exhibit the typical parabolic relationship of pump efficiency to flow rate. Instead, for some pumps, pump efficiency will continue to increase as a function of flow until reaching the maximum allowable flow that can be developed without damaging the pump, also referred to as "pump run-out." Similarly, the expected BEP of some pumps may be only slightly below the maximum allowable flow. For such pumps, it may not be possible to use the procedure described in HI 40.6–2014 to determine the BEP, since the pump cannot safely operate at flows of 110 and/or 120 percent of the expected BEP of the pump. In such cases, DOE proposed in the April 2015 pumps test procedure NOPR that the seven flow points for determination of BEP should be 40, 50, 60, 70, 80, 90, and 100 percent of the expected maximum allowable flow rate of the pump instead of the seven flow points described in section 40.6.5.5.1 of HI 40.6–2014. In addition, in such cases, DOE proposed that the specified constant load flow points should be 100, 90, and 65 percent of the BEP flow rate. 80 FR 17586, 17611 (April 1, 2015).

In response, HI commented that it disagreed with this proposal because in order to determine the location of the BEP, testing must occur at rates of flow greater than 100 percent of expected BEP flow. (HI, No. 8, p. 18) DOE notes that the proposal in the April 2015 pumps test procedure NOPR is specified with respect to the expected maximum allowable flow rate, or the expected BEP, of the pump, not the measured BEP flow. That is, under the NOPR proposal, pumps with the expected BEP occurring at the maximum allowable flow, as defined in ANSI/HI 1.1-1.2–2014, would be tested at the alternative load points specified in test procedure for pumps with BEP at run-out.

DOE acknowledges that pump manufacturers must have some knowledge of the expected operational characteristics of their pump, including the expected BEP and expected maximum allowable flow, in order to determine the appropriate load points for determining BEP. However, DOE notes that this is the case for all pumps, not just pumps with BEP at run-out. That is, the specific load points used to determine BEP for all pumps are specified with respect to the expected operating characteristics of the pump (i.e., BEP flow rate, as specified in section 40.6.5.5.1 of HI 40.6–2014, or maximum allowable flow for pumps with BEP at run-out). DOE believes this is necessary since the BEP and flow characteristics of different load points could vary widely and it is important that the data captured during the test procedure effectively and fully characterize the performance of the pump over the pump's operating ranges. DOE also understands that significant design, engineering, and modeling are involved with creating pump models for specific applications and design parameters and, as such, DOE finds it unlikely that the BEP of a pump will occur at or near a pump's maximum allowable flow without the pump manufacturer having some expectation that this will occur based on the inherent design characteristics of the pump. As such, DOE believes that the proposed test procedure for pumps with BEP at or near run-out is consistent with the HI 40.6–2014 industry test protocols and appropriate for determining the performance of such pumps and no additional changes are necessary. DOE also notes that the maximum efficiency point (or BEP), in the case of pumps with BEP at the maximum allowable flow rate will occur at the maximum flow rate tested and will not be a parabolic maxima, as is the case for most pumps.

DOE notes that, in the April 2015 NOPR, DOE referred to pumps with BEP at run-out as corresponding to those with their expected BEP at the expected maximum allowable flow. DOE recognizes that pumps with their maximum allowable flow occurring between 100 and 120 percent of BEP flow would also not be able to be tested in accordance with the proposed test procedure, as not all of the load points specified in the procedure could be measured in accordance with the test procedure. As such, DOE is adopting, in this final rule, the proposal described in the April 2015 pumps test procedure NOPR, except that DOE is clarifying that pumps with maximum allowable flow occurring between 100 and 120 of BEP flow also qualify as pumps with BEP at run-out and must apply the appropriate test procedure. To ensure that the DOE test procedure is consistent and adequately captures the range of flow rates with which the pump is expected to operate, DOE is maintaining in this final rule that load points for determination of BEP are specified with respect to the expected maximum allowable flow of the pump, for pumps with the expected BEP within 20 percent of the expected maximum allowable flow. In the final rule, DOE is also clarifying the specific load points that must be used in determining pump or driver input power in accordance with the procedure described in section III.C.2.d.

e. Measurement Equipment for Testing-Based Methods

In the April 2015 pumps test procedure NOPR, DOE noted that HI 40.6–2014 does not contain all the necessary methods and calculations to determine pump power consumption for the range of equipment that will be addressed by this final rule (i.e., pumps inclusive of motors and continuous or non-continuous controls). For the purposes of determining most quantities relevant to the determination of PEI_{CL} or PEI_{VL} for pumps rated using the calculation-based methods, DOE proposed to incorporate by reference HI 40.6–2014, appendix C, which specifies the required instrumentation to measure head, speed, flow rate, torque, temperature, and electrical input power to the motor. However, DOE noted that, for the purposes of measuring input power to the driver for pumps sold with a motor and continuous or non-continuous controls rated using the testing-based method, the equipment specified in section C.4.3.1, “electric power input to the motor,” of HI 40.6–2014 may not be sufficient. Based on the specifications in CSA C838–13 and AHRI 1210–2011, since these test standards are the most relevant references for measuring input power to such controls, DOE proposed that electrical measurements for determining VSD efficiency be taken using equipment capable of measuring current, voltage, and real power up to at least the 40th harmonic of fundamental supply source frequency[63] and have an accuracy level of ±0.2 percent of full scale when measured at the fundamental supply source frequency. 80 FR 17586, 17611-12 (April 1, 2015).

DOE requested comment on the type and accuracy of required measurement equipment, especially the equipment required for electrical power measurements for pumps sold with motors having continuous or non-continuous controls. AHRI commented that AHRI 1210-2011 specifies appropriate power supply tolerances so that both pump manufacturers and DOE enforcement testing can be confident with the establishment and verification of ratings of VFDs sold with pumps. (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. In addition, AHRI notified DOE that VFD manufacturers are

[63] CSA C838–13 requires measurement up to the 50th harmonic. However, DOE believes that measurement up to the 40th harmonic is sufficient, and the difference between the two types of frequency measurement equipment will not be appreciable.

working to expand the scope of AHRI 1210-2011 to include a higher horsepower upper limit and to include additional load points.

HI commented that it disagrees with the requirements in AHRI 1210-2011 and CSA C838-13, asserting that they were not agreed to by the CIP Working Group and would be excessively burdensome. (HI, No. 8 at pp. 18–19) HI also indicated that pump manufacturers do not have the same equipment as motor and drive test laboratories and should not be expected to have the same level of instrumentation. HI recommended that DOE instead require the ±2.0 percent maximum permissible measurement device uncertainty specified in Table 40.6.3.2.3 of HI 40.6–2014 for driver input power.

In response to HI's concerns regarding the burden of such additional instrumentation, DOE notes that, in the April 2015 pumps test procedure NOPR proposal, such sophisticated electric measurement equipment was only proposed to be required for the measurement of input power to the continuous or non-continuous control when rating the pump under the testing-based methods. For other pump configurations and when testing a pump using the calculation-based methods, the electrical measurement equipment specified in HI 40.6–2014 section C.4.3.1 of appendix C would apply. DOE also notes that several interested parties, including HI, previously commented 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) HI also previously noted that this additional instrumentation is manageable and within the capabilities of what most of the HI members are doing today. (Docket No. EERE-2011-BT-STD-0031; HI, public meeting transcript, No. 19 at p. 235)

In addition, given the power conditioning requirements adopted in section III.C.2.c, DOE believes that the more sophisticated electrical measurement equipment capable of measuring true root mean square (RMS) voltage, true RMS current, and real power for distorted waveforms is required to ensure that the incoming power is within the specifications for those pump configurations where it is required and that the power measurement is accurate. Specifically, DOE is requiring, as discussed at length in section III.C.2.c, certain voltage, frequency, voltage unbalance, and voltage THD levels be maintained when testing: (1) bare pumps using a calibrated motor, (2) pumps sold with motors using the testing-based methods, and (3) pumps sold with motors and continuous or non-continuous controls using the testing-based method. In order to verify that these requirements are met, measurement equipment must be capable of accurately measuring real power, true RMS voltage, frequency, voltage unbalance, and voltage THD. DOE notes that, in section C.4.3, HI 40.6 specifies that driver input power to the motor should be calculated as the product of (1) line volts, (2) line amps, and (3) power factor. As HI 40.6-2014 specifies the measurement of power factor, DOE believes that the electric equipment capable of measuring at least real power, true RMS voltage, and true RMS current is already required by HI 40.6-2014, as such measurements are necessary for determining power factor.

Some watt meters and watt-hour meters would not be sufficient for accurate measurement of real power for distorted voltage waveforms or distorted current waveforms; this is because such instruments incorrectly assume that the waveforms are perfectly sinusoidal (i.e., free of the harmonics that are introduced by non-linear loads).[64] DOE is therefore requiring the use of instruments that accurately measure true RMS current, true RMS voltage, and real power for distorted waveforms with harmonic frequencies ranging from the fundamental frequency (60 Hz) up to and including the 40th harmonic (2400 Hz).

However, with respect to the required accuracy of any electrical measurement equipment, DOE acknowledges the concern from HI regarding the additional burden associated with acquiring instrumentation consistent with the specifications provided in the NOPR. As such, DOE reviewed available and applicable test methods for motors and controls, including AHRI 1210-2011 and CSA C838-13. DOE notes that AHRI 1210-2011 in turn references IEC 61000-4-7, "Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto," regarding the necessary characteristics for electric measurement equipment. IEC 61000-4-7 provides requirements for Class I instruments and recommends their use where precise measurements are necessary, such as for verifying compliance with standards. The maximum error on power for IEC Class I instruments is ±1 percent of measured value for readings greater than or equal to 150 W

[64] PG&E, "Voltage and Current Measurement of Non-Sinusoidal AC Power" (October 2004, http://www.pge.com/includes/docs/pdfs/mybusiness/customerservice/energystatus/powerquality/nonsinusoidal_power.pdf, accessed September 8, 2015).

(0.2 hp). However, IEC 61000-4-7 states that the error limits refer to single-frequency (i.e., sinusoidal) steady-state waveforms, in the operating frequency range, applied to the instrument under rated operating conditions to be indicated by the manufacturer.

The requirements in IEC 61000-4-7 generally align with those in section 5.7.3 of CSA C390-10, which specifies that motor input power measurements shall have a maximum uncertainty of ±1.0 percent of the reading (including all errors from the power meter, current transformers, and potential/voltage transformers). However, CSA also states that the specified uncertainties shall apply only at the rated full load (i.e., near rated power factor) of the motor under test. While both IEC 61000-4-7 and CSA C390-10 recommend instrument tolerances of ±1.0 percent, DOE notes that their application of that tolerance is not the same as the tolerance DOE is adopting in this final rule, which applies to the measured power at each test point and with the power supply characteristics experienced during the test.

DOE recognizes that the accuracy of input power measurements can be compromised to some extent when voltage and/or current waveforms are displaced and/or distorted. In addition, DOE recognizes that motors will not always be fully loaded during pump testing, that motors may be operated somewhat above nameplate voltage (as allowed in this final rule), and that some distortion of the voltage waveform is permitted in this final rule. Therefore, DOE believes it is appropriate to allow electrical equipment accuracy of ±2.0 percent of measured value, consistent with the tolerance specified in section 40.6.3.2.3 of HI 40.6-2014 and HI's request. DOE is adopting such a requirement in this final rule.

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. DOE is clarifying in this final rule that the combined accuracy of all instruments used to measure a parameter must meet the prescribed accuracy requirements for electrical measurement equipment. 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 shall 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.[65] DOE is therefore using the root sum of squares to calculate the combined accuracy of multiple instruments used in a single measurement, consistent with conventional error propagation methods.

Therefore, in this final rule, DOE is specifying the characteristics of the electrical measurement equipment that must be used when measuring input power to the motor, continuous controls, or non-continuous controls. Specifically, the electrical measurement

[65] 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).

equipment in such cases must be capable of measuring true RMS current, true RMS voltage, and real power up to at least the 40^{th} 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 notes that standard electrical measurement equipment meeting the requirements of HI 40.6–2014 section C.4.3.1 may still be used when testing any pumps under the calculation-based methods (i.e., bare pumps, pump sold with motors, and pumps sold with motors and continuous or non-continuous controls), provided a calibrated motor is not used to determine the pump shaft input power. The electrical measurement equipment requirements being adopted in this pumps test procedure final rule are summarized in Table III.5.

Table III.5 Electrical Measurement Requirements for Different Configurations of Pumps for the Calculation Based and Testing Based Approaches.

Pump Configuration	Electrical Measurement Requirements	
	Calculation-Based Test Method without a Calibrated Motor	Testing-Based Test Method or Calculation-Based Test Method with a Calibrated Motor
Bare Pump	HI 40.6–2014, section C.4.3.1, unless testing with a calibrated motor.	Not Applicable
Pump + Motor or Pump + Motor + Continuous or Non-Continuous Controls	HI 40.6–2014, section C.4.3.1, unless testing with a calibrated motor.	Equipment 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.

While DOE acknowledges that these requirements may represent a burden for some manufacturers and test labs who do not already have such equipment, DOE has minimized the additional burden associated with this requirement, to the extent possible, by only requiring more sophisticated power measurement equipment in those cases where it is necessary to verify that the test procedure power conditioning requirements are being met. DOE also notes that, for many pumps, the testing-based approaches are optional and a manufacturer could elect to determine the PEI using the calculation-based approach and avoid having to purchase and use the more accurate and expensive electrical measurement equipment necessary for conducting testing under the testing-based approach. The burden associated with this test procedure, and in particular the required test equipment, is discussed further in section IV.B.

f. Calculations and Rounding

DOE notes HI 40.6–2014 does not specify how to round values for calculation and reporting purposes. DOE recognizes that the manner in which values are rounded can affect the resulting PER or PEI, and all PER or PEI values should be reported with the same number of significant digits. In the April 2015 pumps test procedure NOPR, DOE proposed to require that all calculations be performed with the raw measured data, to ensure accuracy, and that the PER_{CL} and PEI_{CL} or PER_{VL} and PEI_{VL} be reported to the nearest 0.01. 80 FR 17586, 17612 (April 1, 2015).

DOE requested comment on its proposal to conduct all calculations using raw measured values and that the PER_{CL} and PEI_{CL} or PER_{VL} and PEI_{VL}, as applicable, be reported to the nearest 0.01. In response, HI commented that it understands and agrees that the requirement is to normalize raw data to nominal speed, and the PER_{CL}, PEI_{CL}, PER_{VL} and PEI_{VL} would be reported to the nearest 0.01. (HI, No. 8 at p. 19) In the April 2015 NOPR public meeting, a representative of HI (Paul Ruzicka) suggested that DOE clarify that calculations be performed with "raw normalized data," since all data are to be corrected to nominal speed. (HI, NOPR public meeting transcript, No. 7 at pp. 165-66)

DOE appreciates HI's confirmation of the proposed approach. In response to HI's suggestion that DOE clarify that all calculations are to be performed with "raw normalized data," DOE notes that the normalization to nominal speed is also a calculation and that such calculation is also to be performed with raw measured data. Also, some collected data do not need to be normalized to nominal speed. As such, DOE finds it clearer to continue to specify that all calculations be performed with raw measured data, including the normalization to nominal speed.

In addition, in preparing the final rule test procedure provisions, DOE reviewed the calculations, uncertainty, and significance of measured values used to determine the PER_{CL} and PEI_{CL} or PER_{VL} and PEI_{VL}, as applicable. Based on this analysis, DOE determined that while PEI_{CL} and PEI_{VL} are to be reported to 0.01, the precision of the measurement equipment specified in the NOPR is not sufficient to determine PER_{CL} and PER_{VL} to 0.01, especially for large pumps. As such, in this final rule, DOE is continuing to specify that all calculations be performed with the raw measured data, to ensure accuracy, and that the PEI_{CL} and PEI_{VL} be reported to the nearest 0.01. However, DOE is specifying, in this final rule, that PER_{CL} and PER_{VL} need only be specified to three significant digits, which is equivalent to or better than the level of significance specified for PEI_{CL} and PEI_{VL}. DOE also agrees with HI that all data should be corrected to nominal speed prior to performing subsequent calculations, as described in section III.C.2.c.

D. Determination of Motor Efficiency

The PEI_{CL} and PEI_{VL} metrics both describe the performance of a pump and an accompanying motor, including continuous or non-continuous controls, if applicable. As such, the performance of the applicable motor must be determined to calculate the PEI_{CL} or PEI_{VL} of a given pump model.

In the April 2015 pumps test procedure NOPR, DOE proposed that the motor efficiency would be determined based on the configuration in which the pump was sold. For determining the default motor efficiency of a minimally compliant pump (PER_{STD}) and for determining the default motor efficiency used to calculate PER_{CL} for bare pumps, DOE proposed to specify the nominal full load motor efficiency that corresponds to the applicable Federal minimum standard. For determining PER_{CL} or PER_{VL} for pumps sold with motors or with motors and continuous or non-continuous controls, DOE proposed to use either (1) the physically tested performance of the motor paired with that pump when using testing-based methods, or (2) the represented nominal full load motor efficiency (i.e., the nameplate and certified rating) of the motor (other than submersible) distributed in commerce with that pump model when using the calculation-based test method. 80 FR 17586, 17612–13 (April 1, 2015). The specific procedures for determining the applicable Federal minimum and represented nominal full load motor efficiency values are described in section III.D.1 and III.D.2, respectively.

Based on DOE's proposed test procedure, the applicable Federal minimum or the represented nominal full load motor efficiency would then be used to determine the full load losses, in horsepower, associated with that motor. The full load losses would then be adjusted using an algorithm to reflect the motor performance at partial loads, corresponding to the load points specified in the DOE test. These losses would then be combined with the measured pump shaft input power at each load point to determine the PER_{CL} or PER_{VL} for that pump, as described in section III.B. Id. Section III.E.1 describes how the Federal minimum or represented nominal full load motor efficiency is used in the calculation-based method when calculating overall pump power consumption.

1. Default Nominal Full Load Motor Efficiency

For determining the default motor efficiency of a minimally compliant pump (PER_{STD}) and for determining the default motor efficiency used to calculate PER_{CL} for bare pumps, DOE proposed to specify the nominal full load motor efficiency that corresponds to the applicable Federal minimum standard. In the April 2015 pumps test procedure NOPR, DOE proposed that the "default" nominal full load motor efficiency values be based on the minimum nominal full load motor efficiency standards for polyphase, NEMA Design B motors from 1 to 500 hp, defined in 10 CFR part 431, subpart B for medium and large electric motors, except for submersible motors. Specifically, at the time of the proposal, the values in Table 5 of 10 CFR 431.25(h) defined the nominal full load motor efficiency standards, by number of poles and horsepower for the applicable motors. 80 FR 17586, 17612-13 (April 1, 2015). DOE is using the term "default nominal full load efficiency" throughout this notice to refer to the default values used in this test procedure for determining PER_{STD} and for bare pumps, PER_{CL} corresponding to the applicable Federal minimum energy conservation standards. See section III.D.1.a for a discussion regarding electric motors covered by DOE's energy conservation standards at 10 CFR 431.25 and section III.D.1.b for a discussion regarding submersible motors.

a. Covered Electric Motors

For the determination of PER_{STD} for all pumps (except ST pumps) and PER_{CL} for bare pumps (see section III.E.1.a), default nominal full load motor efficiency values are required. As mentioned previously, DOE believes the nominal full load motor efficiency standards specified for NEMA Design B motors are appropriate for the pumps (except ST pumps) to which this test procedure is applicable. In the April 2015 pumps test procedure NOPR, DOE also proposed to specify the selection of the default motor characteristics used for calculating PER_{CL} and PER_{STD} based on the configuration in which the pump is being sold. Specifically, for bare pumps, DOE proposed that the default nominal full load motor efficiency for determining PER_{CL} and PER_{STD} would be based on the following criteria:

- the number of poles selected for the default motor would be equivalent to the nominal speed of the rated pump (i.e., 2 poles correspond to 3,600 rpm and 4 poles correspond to 1,800 rpm);
- the motor horsepower selected for a given pump would be required to be either equivalent to, or the next highest horsepower-rated level greater than, the measured pump shaft input power at 120 percent of BEP flow, as determined based on an extrapolation of the linear regression of pump input power (discussed in section III.C.2.d); and

- the lower standard (i.e., less stringent) of either the open or enclosed construction at the appropriate motor horsepower and number of poles. 80 FR 17586, 17612-13 (April 1, 2015).

As mentioned previously, the appropriate table at 10 CFR 431.25 is the table of nominal full load motor efficiency standards that is currently required for compliance of NEMA Design B polyphase motors.

For pumps sold either with motors or with motors and continuous or non-continuous controls, selection of a default nominal full load motor efficiency for calculation of PER_{STD} is also required. This default nominal full load motor efficiency is also based on the applicable Federal minimum standards. In this case, DOE proposed that the motor horsepower and number of poles selected for determining the default nominal full load motor efficiency for use in the calculation of PER_{STD} should be equivalent to the horsepower and poles of the motor with which the pump model is distributed in commerce. Similar to the case for bare pumps, DOE also proposed that the default nominal full load motor efficiency corresponding to the minimally compliant motor in PER_{STD} would still be the minimum of the open and enclosed standards for the appropriate motor horsepower and number of poles. That is, regardless of the motor construction (i.e., open or enclosed) of the motor with which the pump is being rated, the minimum nominal full load motor efficiency standard listed in the applicable table for polyphase NEMA Design B motors at 10 CFR 431.25 for the given motor horsepower and number of poles would be used. Id.

DOE requested comment on its proposal to determine the default motor horsepower for rating bare pumps based on the pump shaft input power at 120 percent of BEP flow and, in response, HI commented that it agrees with this proposal. (HI, No. 8 at p. 19) DOE also requested comment on its proposal to specify the default nominal full load motor efficiency based on the applicable minimally allowed nominal full load motor efficiency specified in DOE's energy conservation standards for NEMA Design B motors at 10 CFR 431.25 for all pumps except pumps sold with submersible motors. HI commented that each NEMA MG 1 nominal efficiency value is the average efficiency of a large population of motors of the same design, so for any given nominal efficiency value, half of the corresponding population would be lower. (HI, No. 8 at p. 19) HI indicated that the NEMA MG 1 minimum efficiency values should be used instead so that the test method for determining PEI_{CL} and PEI_{VL} are not disadvantaged. Wilo similarly commented that the use of NEMA nominal efficiencies would cause 50 percent of borderline pumps to fail. (Wilo, Docket No. EERE-2011-BT-STD-0031, No. 44 at p. 2)

DOE acknowledges the comments from HI and Wilo regarding the use of nominal full load motor efficiency values from 10 CFR 431.25. DOE notes that these values represent the minimum Federal efficiency standard for applicable covered motors and, as such, believes that referencing an alternative, lower efficiency value would be inappropriate and inconsistent with DOE's regulatory framework. However, in response to the specific concern voiced regarding a potential disadvantage when using the testing-based method, DOE will follow the method the manufacturer used to determine the representative value when conducting enforcement testing. In other words, if a pump manufacturer has used the calculation-based rating method to determine the representative value for a pump basic model, then DOE would also use the calculation-based approach, which relies on the nominal full load motor efficiency values from the table and not the actual motor tested performance. Conversely, if a manufacturer elected to use the testing-based approach, DOE would also assess compliance using the testing-based approach which would account for the actual tested efficiency of the motor incorporated into the pump. Thus, a manufacturer need not be concerned that the actual efficiency of an individual motor would have a disparate effect on the measured efficiency during assessment or enforcement testing.

In this final rule, DOE is adopting the default nominal full load motor efficiency values for bare pumps and the method for determining PER_{STD} proposed in the April 2015 pumps test procedure NOPR. That is, the default nominal full load motor efficiency for bare pumps and for determining PER_{STD} for all pumps (besides VTS pumps) is determined by referencing the applicable energy conservation standards found at 10 CFR 431.25 for NEMA Design B motors that are required at the time the pump model is being certified. At the time of publication of this notice, the appropriate motor Federal energy conservation standards for NEMA Design B polyphase motors can be found at 10 CFR 431.25(h).

DOE notes that, if DOE were to amend the energy conservation standards for NEMA Design B polyphase motors, the represented values for pump PEI would no longer remain valid, and manufacturers would need to revise their represented values to reflect the amended nominal full load motor efficiency standards and recertify at the first annual certification date after the compliance date for the amended motor Federal energy conservation standards. As a result of the methodology being adopted today, which will result in changes to represented values for pumps when the Federal energy conservation standards for NEMA Design B polyphase motors changes, DOE does not believe that any actual design or manufacturing changes will be required from the pump manufacturer since the bare pump will remain the same and is unaffected by the motor standard. Instead, DOE is ensuring that pump ratings still reflect differential representations depending on the efficiency of the motor that is being sold with the pump. DOE understands that certain motors that were minimally compliant with the previous motor standard may no longer be able to be sold once manufacturers are required to comply with amended standards for motors (if adopted) and thus, DOE believes a methodology which reflects this reality is best. Because the PEI is an indexed value that is meant to compare the performance of the pump being tested to that of a theoretical "minimally-compliant" pump, the default nominal full load motor efficiency for that "minimally-compliant pump" must reflect any changes in the motor standard and available products in the market. If DOE did not adopt a methodology that acknowledges potential changes to the energy conservation standards for NEMA Design B motors, then pump represented values could be artificially inflated when compliance with amended energy conservation standards for motors is required and could result in a situation where a compliant pump could be less efficient due to the credit being given from the amended energy conservation standards for motors.

For these reasons, DOE is specifying in the pumps test procedure adopted in this final rule that when determining PER_{STD} for all pumps (except VTS pumps) and PER_{CL} for bare pumps, the default nominal full load motor efficiency value that is used must be the energy conservation standard for NEMA Design B polyphase motors that is required at the time the pump model is being certified and must be updated with an annual certification. As this amended default nominal full load motor efficiency will occur in both the numerator and the denominator of the PEI metric, such a test procedure provision will not lead to changes in the relative ratings of bare pump models using the calculation-based approach.

b. Submersible Motors

DOE notes that submersible motors are not currently subject to the DOE energy conservation standards for electric motors specified at 10 CFR 431.25. Therefore, for the purposes of calculating PEI_{CL} for bare VTS pumps or PER_{STD} for any pumps sold with submersible motors, DOE requires a default assumption regarding full load efficiency for submersible motors. In the April 2015 pumps test procedure NOPR, DOE constructed a table of motor full load efficiencies by motor horsepower, similar to the table of energy conservation standards for electric motors at 10 CFR 431.25(h), as shown in Table III.6. 80 FR 17586, 17614-15 (April 1, 2015).

As it was not DOE's intent to impact the rated efficiency of submersible motors through this rulemaking, DOE deflated the minimum submersible motor efficiency that DOE observed by using the maximum number of "bands" across a horsepower range to ensure that the value represented a worst-case value. Where no data were available, DOE applied the same number of NEMA bands across the range of motor horsepower and numbers of poles.

Table III.6 Two-Pole Motor Submersible Motor Full Load Efficiency by Motor Horsepower Relative to the Full Load Efficiency in in Table 5 of 10 CFR 431.25(h)

Motor Horsepower hp	Minimum Observed Full Load Efficiency (2-poles) %	Observed Number of "Bands" Below the Full Load Efficiency in Table 5 of 10 CFR 431.25(h)	Default Number of "Bands" Below the Full Load Efficiency in Table 5 of 10 CFR 431.25(h)
1	67	6	11
1.5	67	11	
2	73	9	
3	75	9	
5	76	10	
7.5	77	10	15
10	75	13	
15	72.2	15	
20	76.4	13	
25	79	12	
30	79.9	12	12
40	83	10	
50	83	11	
60	84	11	
75	83.8	12	
100	87	10	14
125	86	13	
150	86	13	
175	88	12	
200	87	14	
250	87	14	

Id.

In response to the April 2015 pumps test procedure NOPR proposal, HI commented in the public meeting that several of the minimum motor efficiency values are higher than what is being published. (HI, NOPR public meeting transcript, No. 7 at pp. 159–60). In written comments, HI provided corrected efficiencies for several values. (HI, No. 8 at pp. 19–20).

DOE thanks HI for submitting data to assist in constructing a submersible motor efficiency table that is representative of minimally efficient submersible motors. DOE has revised its proposed submersible efficiency values to accommodate the lower values provided by HI, as shown in Table III.7.

Table III.7 Revised Submersible Motor Full Load Efficiency by Motor Horsepower

Motor Horsepower hp	Minimum Observed Full Load Efficiency %		Observed Number of "Bands" Below the Full Load Efficiency in Table 5 of 10 CFR 431.25(h)		Binned Number of "Bands" Below the Full Load Efficiency for NEMA Design B Motors in CFR 431.25		Resulting Default Nominal Full Load Submersible Motor Efficiency	
	2 poles	4 poles	2 poles	4 poles	2 poles	4 poles	2 poles	4 poles
1	67	-	6	-	11	11	55	68
1.5	67	-	11	-			66	70
2	73	-	9	-			68	70
3	75	-	9	-			70	75.5
5	76	-	10	-			74	75.5
7.5	77	-	10	-	15	15	68	74
10	75	-	13	-			70	74
15	72.2	-	15	-			72	75.5
20	76.4	-	13	-			72	77
25	79	-	12	-			74	78.5
30	79.9	81.8	12	13	13	14	77	80
40	83	-	10	-			78.5	81.5
50	83	85.1	11	13			80	82.5
60	82.4	85.4	13	14			81.5	84
75	83.8	86.2	12	14			81.5	85.5
100	87	-	10	-	14	15	81.5	84
125	86	-	13	-			84	84
150	86	86.1	13	-			84	85.5
200	87	-	13	15			85.5	86.5
250	87	-	14	-			86.5	86.5

During the April 2015 NOPR public meeting, Nidec Corporation (Nidec) expressed that the levels of submersible motors should be consistent with the requirements for vertical motors. Nidec also stated that there be two sets of default efficiency values: one for a dry rotor and one for a wet rotor. (Nidec, NOPR public meeting transcript, No. 7 at pp. 160–61) Nidec added that the type with air could use Table 12-12 from NEMA MG 1. (Nidec, NOPR public meeting transcript, No. 7 at p. 163)

In response to Nidec's comment, DOE notes that all equipment categories that are subject to the test procedure, including VTS pumps that are most commonly paired with submersible motors, are defined as dry rotor pumps. As such, wet rotor submersible motors and wet rotor submersible pumps are not subject to the test procedure, and a table of minimum efficiency values for them is not necessary. DOE notes that, in response to Nidec's comment regarding "the type [of motor] with air," DOE believes Nidec is referring to non-hermitically sealed units (i.e., non-submersible motors) and confirming that Table 12-12 in NEMA MG-1 (which is consistent with DOE's minimum efficiency standards for electric motors at 10 CFR 431.25) is appropriate for such non-submersible motors. While DOE's application of the minimum efficiency standards for electric motors in this final rule is limited to NEMA Design B motors, DOE notes that NEMA's comment is consistent with the approach being taken in this final rule.

HI stated that DOE needs to emphasize that single-phase motors are not part of the minimum efficiency tables. (HI, No. 8 at pp. 19–21) DOE notes that in this test procedure, as described in section III.A.6, all pumps sold with single-phase motors, including single-phase submersible motors, may be rated as bare pumps in order to not be penalized for the inherently lower efficiencies of single-phase equipment. In the bare pump approach, the default submersible motor efficiency values presented in Table III.7 are used in calculating both the numerator (PER_{CL} or PER_{VL}) and denominator (PER_{STD}) of PEI; the lower efficiency of a single-phase motor is not taken into account. DOE notes that, as described in section III.A.6, pumps sold with single-phase submersible motors may also apply the testing-based approach, if desired by the manufacturer. However, in such a case, the default motor efficiency used to determine PER_{STD} would continue to be the default nominal submersible motor efficiency presented in Table III.7.

In regard to selection of default motor size for submersible motors, in the April 2015 pumps test procedure NOPR, DOE proposed to apply the same sizing method proposed for other categories of pumps, described in section III.D.1 of this NOPR. At the April 2015 NOPR public meeting, HI stated that submersible motors are sold utilizing full NEMA motor service factors and recommended amending the submersible motor sizing to account for this sizing approach. (HI, NOPR public meeting transcript, No. 7 at p. 150) In its written comments, HI noted that DOE needs to emphasize that submersible pumps are typically loaded to the fully utilized service factor of the motor. (HI, No. 8 at pp. 19–20)

In response to HI's suggestion, DOE has reviewed the typical service factors of submersible motors offered for sale with pumps within the scope of this test procedure.

DOE determined that the majority of submersible motors exhibited service factors of 1.15. DOE notes that this value is also consistent with the service factor prescribed in table 12-4 of NEMA MG-1 2009 for Design A, B, and C polyphase, squirrel cage, general-purpose, alternating-current motors of the open type with a motor horsepower greater than 1 hp. In light of this, DOE is revising its requirements for the default motor sizing of submersible motors in this final rule to reflect the service factors observed in the industry. That is, DOE is specifying that, for VTS bare pumps, the default submersible motor horsepower be determined as the motor horsepower that is equal to or the next highest motor horsepower greater than the pump shaft input power (in horsepower) at 120 percent of BEP flow divided by the service factor, or 1.15. DOE notes that some motors less than 3 horsepower may have a higher service factor, but by using the same value for all pumps, DOE is simplifying the procedure and does not expect this simplification to significantly impact the PEI for VTS bare pumps. This is because the same service factor (1.15) is used for the given pump's PER_{CL} and for PER_{STD}, so the two efficiency values essentially cancel out and do not significantly impact the rating.

DOE reiterates that this default service factor is only necessary for determining the default motor efficiency for submersible motors. For pumps sold with submersible motors and pumps sold with submersible motors and continuous or non-continuous controls, the actual submersible motor size with which the pump is distributed in commerce is used when determining motor efficiency for use in calculating PER_{CL}, PER_{VL}, and PER_{STD}.

In summary, in this final rule, DOE will allow the use of default nominal full load submersible motor efficiency values presented in Table III.7 to rate (1) VTS bare pumps, (2) pumps sold with submersible motors, and (3) pumps sold with submersible motors and continuous or non-continuous controls as an option instead of using the testing-based approach. DOE believes that allowing the calculation-based method to be used for pumps sold with submersible motors may also reduce the testing burden for some manufacturers. However, if manufacturers wish to account for the use of submersible motors with a higher efficiency than the default nominal full load submersible motor efficiency, they may choose to rate the pump model using the testing-based, wire-to-water method described in section III.E.2.

2. Represented Nominal Full Load Motor Efficiency for Pumps Sold with Motors

For pumps sold with motors or motors and continuous or non-continuous controls that are rated using the calculation-based approach, DOE proposed in the April 2015 pumps test procedure NOPR that the nominal full load motor efficiency used in determining the PER_{CL} or PER_{VL} will be the value that is certified to DOE as the nominal full load motor efficiency in accordance with the standards and test procedures for electric motors at 10 CFR 431, subpart B. 80 FR 17586, 17613-14 (April 1, 2015). As noted in the April 2015 pumps test procedure NOPR and described in greater detail in section III.E.1.b and III.E.2, this verifiable and standardized represented nominal full load motor efficiency is only available for motors that are subject to DOE's test procedure for electric motors and, as such, DOE proposed in the April 2015 pump test procedure NOPR, that only pumps sold with motors subject to DOE's electric motor test procedure and energy conservation standards would be able to conduct the proposed calculation-based approach. Id. at 17618, 17626–28. DOE notes that these represented nominal full load efficiency values correspond to the certified value submitted on the motor manufacturer's certification report and on the nameplate of the motor itself. Therefore, if the motor manufacturer elects to certify conservatively at the Federal energy conservation standard level, this is the value the pump manufacturer must use in its calculations for pumps sold with motors subject to DOE's Federal energy conservation standards.

For pumps sold with submersible motors and rated using the calculation-based approach, DOE also proposed that the nominal full load motor efficiency values would be the same as the default nominal full load submersible motor efficiency values used to determine the PER_{CL} for bare pumps and PER_{STD}. Id. at 17614. These values are representative of minimally efficient submersible motors and are discussed further in section III.D.1.b. As noted previously, if manufacturers wish to represent the efficiency of pumps sold with submersible motors that are more efficient than the assumed value, then they may perform the testing-based method described in section III.E.2.b in section.

DOE received no comments on these proposals and is adopting the provisions for specifying the represented nominal full load motor efficiency for motors subject to DOE's electric motor test procedure and the default nominal full load submersible motor efficiency for submersible motors, as proposed. DOE notes that, for pumps sold with motors not addressed by DOE's electric motor test procedure (except submersible motors), the calculation-based methods described in section III.E.1.b would not apply, and no assumption regarding nominal efficiency of the motor paired with the pump is permitted when determining PER_{CL} or PER_{VL}. However, an assumption regarding the default efficiency of the minimally compliant motor that can be paired with a given pump would still be required to calculate PER_{STD}. See Section III.D.1; 80 FR 17586, 17613-14 (April 1, 2015).

3. Determining Part Load Motor Losses

As described in section III.B.2, default nominal full load motor efficiency is converted to motor losses, in horsepower, at each load point to determine the input power to the motor when determining PER_{STD}. This same approach is used to determine PER_{CL} under the calculation-based approach, which is described in greater detail in section III.E.2.b. In the April 2015 pumps test procedure NOPR, DOE proposed to determine the part load losses of the motor at each load point by applying an algorithm to the full load losses of the motor. 80 FR 17615. Specifically, DOE proposed to determine a part load loss factor (y_i) at each load point based on the following equation (13):

$$y_i = \left(-0.4508 \times \left(\frac{P_i}{\text{MotorHP}}\right)^3 + 1.2399 \times \left(\frac{P_i}{\text{MotorHP}}\right)^2 - 0.4301 \times \left(\frac{P_i}{\text{MotorHP}}\right) + 0.6410\right) \quad \textbf{(13)}$$

Where:

y_i = the part load loss factor at load point i,

P_i = the shaft input power to the bare pump at load point i (hp),

MotorHP = the motor horsepower (hp), and

i = load point corresponding to 75, 100, or 110 percent of BEP flow for uncontrolled pumps or 25, 50, 75, or 100 percent of BEP flow for pumps sold with a motor and continuous or non-continuous controls.

Id.

In the proposal, the full load losses of the motor would be determined based on the full load motor efficiency, which would be the default nominal full load motor efficiency described in section III.D.1 for bare pumps and when determining PER_{STD}, or the represented nominal full load motor efficiency described in section III.D.2 for pumps sold with applicable motors. Specifically, DOE proposed that the full load motor losses would be calculated as shown in equation (14):

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/_{100}\right]} - MotorHP \qquad \textbf{(14)}$$

Where:

L_{full}[66] = motor losses at full load (hp),

MotorHP = the motor horsepower (hp), and

$\eta_{motor,full}$ = the default or rated nominal full load motor efficiency as determined in accordance with section III.D.1 or III.D.2, respectively (%).

Id.

[66] DOE notes that, in the April 2015 pumps test procedure NOPR, DOE proposed to define this term using the nomenclature $L_{full,default}$ and described it as equivalent to "default motor losses at full load." However, upon further review, DOE finds this terminology confusing because this equation applies both to pumps rated as bare pumps, for which a default nominal full load motor efficiency applies, as well as pumps rated with motors and pumps rated with motors and controls, for with the nominal full load motor efficiency with which the pump is rated applies (not a default value), depending on the context. Therefore, in this final rule, DOE is updating the terminology to use the nomenclature L_{full} and describe the term as equivalent to "motor losses at full load," referencing the relevant procedure for determining full load motor losses based on the pump configuration.

Finally, DOE proposed that the part load losses at each specified load point would be determined based on the product of the full load losses and the part load loss factor at that load point, as shown in equation (15):

$$L_i = L_{full} \times y_i \qquad \textbf{(15)}$$

Where:

L_i = motor losses at load point i (hp),

L_{full} = motor losses at full load (hp),

y_i = part load loss factor at load point i, and

i = load point corresponding to 75, 100, or 110 percent of BEP flow for uncontrolled pumps or 25, 50, 75, or 100 percent of BEP flow for pumps sold with a motor and continuous or non-continuous controls.

These calculated part load motor losses at each of the specified load points would then be combined with the measured pump shaft input power and weighted equally to calculate PER_{CL} or PER_{VL} via the calculation-based approach and PER_{STD}, as described in section III.E.1.b and III.B.2, respectively. Id. at 17615-16.

DOE requested comment on the development and use of the motor part load loss factor curves to describe part load performance of covered motors and submersible motors, including the default motor specified in section III.D.1 for bare pumps and calculation of PER_{STD}. DOE received no comments on the proposal and, as such, is adopting the proposed methodology presented in the April 2015 pumps test procedure NOPR with no modification for pumps, except those sold with submersible motors. DOE notes that, in making the change requested by interested parties to account for service factor in sizing submersible motors (see section III.D.1.b), DOE is making a slight modification to the part load loss factors for VTS pumps to specify that where $\frac{P_i}{MotorHP}$ >1, a value of 1.000 should be used as the part load loss factor.

This change is needed because the proposed part load loss curves were not developed to be representative of performance above the full load of the motor. This modification implicitly assumes that the motor efficiency curve is flat between full load and the service factor (i.e., 1.15). DOE expects the full load losses of the motor to be more representative of the performance of motors beyond full load operation than extending the curve, which would assume that losses would decrease (efficiency would increase) above full load. DOE has not made any other revisions to the part load loss factors. DOE also notes that such is the case for all pumps; that is, the ratio of pump shaft input power to motor horsepower should not exceed a value of 1 for any pump. As such, to ensure that the part load loss factor equation is not applied inappropriately, DOE is adding this clarification as applicable to all pumps tested under the test procedure.

E. Test Methods for Different Pump Configurations

As previously discussed, the PEI_{CL} and PEI_{VL} for a given pump is determined by first calculating the PER_{CL} or PER_{VL}, as applicable, for the given pump. For all pumps, the PER_{CL} or PER_{VL} is then scaled based on a calculated PER_{STD} (i.e., the PER_{CL} of a pump that would minimally comply with the applicable standard). (Docket No. EERE-

2011-BT-STD-0031) The process for determining the PER_{STD} is described in section III.B.2.

In the April 2015 pumps test procedure NOPR, DOE proposed that different test methods for determining the PER_{CL} and PER_{VL} of applicable pumps would apply based on the configuration of the pump model and the characteristics of the motor and controls it may be sold with. 80 FR 17586, 17616 (April 1, 2015). For example, the available test method(s) for pumps sold alone (i.e., bare pumps) would be different than those for pumps sold with motors or pumps sold with motors and continuous or non-continuous controls. Further, the available test methods for pumps sold with motors that are covered by DOE's energy conservation standards for electric motors at 10 CFR 431.25(g) (as established by the energy conservation standards established in the May 2014 medium electric motor energy conservation standard final rule (79 FR 30933 (May 29, 2014))[67] would be different than the available test methods for pumps sold with motors that are not covered by DOE's test procedure for electric motors. Specifically, DOE proposed defining the applicability of the proposed test methods based on the following:

- two potential approaches: (1) testing-based versus (2) calculation-based;
- three potential configurations: (1) bare pumps, (2) pumps sold with motors, and (3) pumps sold with motors and controls; and
- two different sub-configuration criteria:

[67] DOE recognizes that the scope of the electric motor standards at 10 CFR 431.25 may change in the future as a result of potential future rulemakings. Since the scope of such future motors standards is unknown, DOE wishes to clearly and unambiguously establish the specific motors which, when sold with an applicable bare pump, would be eligible to apply the calculation-based test methods described in this section.

1) whether the pump was sold with: (a) a motor covered by DOE's electric motor energy conservation standards, (b) a submersible motor, (c) a motor that is not covered by DOE's electric motor energy conservation standards and is not a submersible motor, or (d) no motor; and
2) whether the pump was sold with: (a) continuous controls, (b) non-continuous controls, or (c) neither continuous or non-continuous controls.

The applicability of DOE's proposed test methods to different configurations of pumps is summarized in Table III.8. Id. at 17627.

Table III.8 Applicability of Calculation-Based and Testing-Based Test Procedure Options Based on Pump Configuration

Pump Configuration	Pump Sub-Configuration	Calculation-Based Test Method	Testing-Based Test Method
Bare Pump	Bare Pump	A.1: Tested Pump Efficiency of Bare Pump + Default Nominal Full Load Motor Efficiency + Default Motor Part Load Loss Curve	Not Applicable
Pump + Motor	Pump + Motor Covered by DOE's Electric Motor Energy Conservation Standards OR Pump + Submersible Motor	B.1: Tested Pump Efficiency of Bare Pump + Represented Nominal Full Load Motor Efficiency for Actual Motor Paired with Pump + Default Motor Part Load Loss Curve	B.2: Tested Wire-to-Water Performance
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors)	Not Applicable	B.2: Tested Wire-to-Water Performance
Pump + Motor + Speed Controls	Pump + Motor Covered by DOE's Electric Motor Energy Conservation Standards + Continuous Control OR Pump + Submersible Motor + Continuous Control	C.1: Tested Pump Efficiency of Bare Pump + Represented Nominal Full Load Motor Efficiency for Actual Motor Paired with Pump + Default Motor/Control Part Load Loss Curve + Assumed System Curve	C.2: Tested Wire-to-Water Performance
	Pump + Motor Covered by DOE's Electric Motor Energy Conservation	Not Applicable	C.2: Tested Wire-to-Water Performance

	Standards + Non-Continuous Control OR Pump + Submersible Motor + Non-Continuous Control		
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors) + Continuous or Non-Continuous Controls	Not Applicable	C.2: Tested Wire-to-Water Performance

DOE's proposed applicability of testing-based and calculation-based test methods, as shown in Table III.8, was designed to maximize the number of pumps that can be rated using the less burdensome calculation-based methods A.1, B.1, and C.1. DOE also proposed the applicability of the various test methods to maximize flexibility in rating equipment. That is, where possible, DOE proposed to allow either the calculation-based or the testing-based method to be used to determine the PEI of applicable pump models. 80 FR 17627–28. In this case, if a manufacturer wished to represent the improved performance of a given pump, for example from a motor with improved part load efficiency performance, and believed that the assumptions made in the calculation method would not adequately represent the improved performance of that pump, the manufacturer would be able to use the testing-based methods to rate the PEI_{CL} or PEI_{VL} of that pump model to capture the improved performance of the pump as tested.

DOE also noted that, since the measured performance of individual units can vary from the average performance of the population or from DOE's assumed values used in the calculation-based approach, it is theoretically possible for the calculation-based approach to generate ratings that are better or worse than the testing-based approach. To address this possibility, DOE proposed that manufacturers report the test method (i.e., calculation-based or testing-based) used to determine the PEI for each model and that DOE would use the same method used by the manufacturer to generate the rating when performing assessment or enforcement testing. Id. at 17628.

DOE requested comment on its proposal to establish calculation-based test methods as the required test method for bare pumps and testing-based methods as the required test method for pumps sold with motors that are not regulated by DOE's electric motor energy conservation standards, except for submersible motors, or for pumps sold with any motors and with non-continuous controls. DOE also requested comment on the proposal to allow either testing-based methods or calculation-based methods to be used to rate pumps sold with continuous control-equipped motors that are either (1) regulated by DOE's electric motor standards or (2) submersible motors. In addition, DOE requested comment on the level of burden associated with reporting the test method used by a manufacturer to certify a given pump basic model as compliant with any energy conservation standards DOE may set.

HI commented that it agrees with these proposals, and that it is not too burdensome to note the test method in the certification report, as proposed in the April 2015 pumps test procedure NOPR. (HI, No. 8 at p. 23) Wilo commented that the calculation-based test methods should be eliminated entirely. Wilo indicated that one problem is that DOE is not responsible for providing tools to determine compliance, so each manufacturer will be responsible for creating its own potentially erroneous evaluation tool. Wilo also indicated that a second problem is that there are no standard efficiencies for VFDs, so a manufacturer could use a minimally performing VFD to create a better performing PEI value for a given pump sold with motor and controls. (Wilo, Docket No. EERE-2011-BT-STD-0031, No. 44 at pp. 3–4)

In response to Wilo's comment regarding the calculation-based approach, DOE notes that DOE developed the calculation-based approach with extensive feedback and input from the CIP Working Group and believes that it is appropriate for the categories and configurations of pumps for which DOE proposed it would be applicable. DOE also notes that, as described in the April 2015 pumps test procedure NOPR, the calculation-based approach is significantly less burdensome than the testing-based approach since a manufacturer may elect to determine the PEI rating for several pump models sold with different combinations of motors and/or continuous controls based on the physical test of the bare pump only. That is, manufacturers may test a representative sample of bare pumps (see section III.G for a description of DOE's sampling provisions for pumps) and all subsequent ratings of that bare pump sold with any combination of motors that are covered by DOE's energy conservation standards, submersible motors, and continuous controls may be calculated using the calculation-based approach with no additional physical testing. Due to the potentially large burden associated with requiring physical testing of each potential combination of a bare pump, motor, and continuous control, as well as the existing concerns of manufacturers and other interested parties regarding the proposed test procedure (see section IV.B), DOE is electing to maintain the calculation-based procedure as an option for applicable pumps.

DOE also notes that the calculation-based procedure is required for bare pumps, as testing-based methods do not apply to bare pumps because a PEI rating (which includes the efficiency of the motor) cannot be determined based on a test of the bare pump alone. For all other pump configurations, the calculation-based method is only offered as an option, should manufacturers choose to employ it. Therefore, if Wilo prefers to use the testing-based approach to certify their equipment, it may do so for all configurations of pumps except bare pumps.

Regarding the accuracy or validity of any evaluation tools to implement any calculations associated with either the calculation-based or testing-based approach, DOE notes that manufacturers must rate pumps in accordance with the test procedure. The calculation-based approach required by the regulations provides sufficient detail for manufacturers to develop reliable tools. Nonetheless, manufacturers are responsible for ensuring that any calculations are performed correctly, whether performed using an evaluation tool or by hand, for both the calculation-based and the testing-based approaches.

In response to Wilo's comment regarding the potential for a manufacturer to improve the PEI rating of a given pump model sold with a motor, but without continuous controls, by pairing the pump with continuous controls, DOE acknowledges that the PEI for pumps sold with continuous controls tested using either the calculation-based or testing-based approach will be better (i.e., lower) than that of the same pump sold and tested with a motor only. However, consistent with the feedback provided by the CIP

Working Group, DOE believes that decreased PEI is reflective and representative of the improved energy performance customers are likely to observe in the field. That is, the load points and, in the case of controlled-motors, the system curve, assumed for these pumps (discussed in section III.B and III.E.2.c, respectively) are representative of the operation of such pumps in the field. DOE also notes that, as mentioned in the April 2015 pumps test procedure NOPR, the testing-based method is intended to allow for more granular differentiation of equipment performance, including differentiation of the performance of different models or styles of continuous controls. In particular, DOE noted in the April 2015 pumps test procedure NOPR that the ability of the testing-based method to differentiate among the performance of various continuous controls was particularly important for pumps sold with motors and continuous controls, since DOE is only assuming a single system performance curve to represent all applicable continuous controls, as described in section III.E.1.c, and the testing-based method may provide an opportunity for manufacturers to differentiate among the performance of different continuous control technologies. Id. at 17627–28.

In this test procedure final rule, DOE is adopting the test method applicability proposed in the April 2015 pumps test procedure NOPR and shown in Table III.8 with no modifications. As proposed in the NOPR, DOE is also adopting requirements that manufacturers report the test method used to determine the ratings for applicable pump models and provisions that when conducting assessment and enforcement testing DOE will use the same method reported by manufacturers.

The specific test methods, any comments DOE received on the proposed methods and applicability, and the final test methods DOE is adopting in this final rule are discussed in the following sections:

- section III.E.1.a: the calculation-based approach for bare pumps (method A.1),
- section III.E.1.b: the calculation-based approach for pumps sold with applicable motors,
- section III.E.1.c: the calculation-based approach for pumps sold with applicable motors and continuous controls,
- section III.E.2.b: the testing-based approach for pumps sold with motors, and
- section III.E.2.c: the testing-based approach for pumps sold with motors and continuous or non-continuous controls.

1. Calculation-Based Test Methods

In the April 2015 pumps test procedure NOPR, DOE proposed that the following calculation-based test methods would be used to rate (1) pumps sold as bare pumps (method A.1); (2) pumps sold either with (a) motors that are regulated by DOE's electric motor standards or (b) submersible motors (method B.1); and (3) pumps sold with motors that are either (a) regulated by DOE's electric motor standards or (b) submersible motors, and that are equipped with continuous controls[68,69] (method C.1). 80 FR 17586, 17616 (April 1, 2015).

Regardless of the pump configuration or characteristics, the calculation-based test method for the applicable pump types includes the following steps:

1) Physical testing of the bare pump, in accordance with HI 40.6–2014, to determine the pump BEP and pump shaft input power at 75, 100, and 110 of actual BEP flow, adjusted to nominal speed;
2) Determining the part load losses of the motor (or default motor) and any continuous or non-continuous controls applicable to the rated pump model at each load point;
3) Taking the sum of the pump shaft input power at nominal speed and the calculated part load motor losses at each load point in the constant load or variable load profiles, as applicable, to determine the input power to the pump at each load point;
4) Determining the PER_{CL} or PER_{VL}, as applicable, for the given pump as the weighted average of the input power to the pump at the applicable load points;

[68] The calculation-based test method was designed to capture the dynamic response of a control that can continuously respond to changes in load and reduce power consumption at all load points below BEP. Therefore, pumps sold with non-continuous controls would instead use the testing-based method described in section III.E.2.c, which captures some reduction in power consumption at some reduced flow rates. DOE discussed this approach with the CIP Working Group, which generally agreed with it, although such a recommendation was not specifically included in the CIP Working Group recommendations. (Docket No. EERE-2013-BT-NOC-0039, No. 107 at pp. 49–50)

[69] DOE notes that some pumps sold with continuous controls, such as pumps sold with ECMs, may not be eligible to apply the calculation-based method based on the fact that ECMs are not: (1) a type of motor covered by DOE's energy conservation standards for covered motors or (2) a submersible motor (see section III.E). These pumps would instead apply a testing-based method.

5) Determining the PER_{STD} for the minimally compliant pump, as described in section III.B.2; and

6) Dividing the PER_{CL} or PER_{VL} from step 4 by the PER_{STD} for that pump model to determine PEI_{CL} or PEI_{VL}, respectively.

The specific test methods for bare pumps, pumps sold with motors, and pumps sold with motors and continuous controls are described in more detail in the following sections III.E.1.a, III.E.1.b, and III.E.1.c, respectively.

a. Calculation-Based Test Method A.1: Bare Pump

As described previously, DOE proposed in the April 2015 pumps test procedure NOPR that the bare pump PER_{CL} would be determined based on the measured pump shaft input power at 75, 100, and 110 percent of BEP flow. 80 FR 17586, 17616-17 (April 1, 2015). Section III.C of this final rule describes the test method for determining pump shaft input power at the specified load points, which is based on HI 40.6–2014. DOE proposed that the measured pump shaft input power at the three constant-load flow points would then be combined with the part load motor losses at each load point and equally weighted to determine PER_{CL} for that bare pump, as shown in equation (16):

$$\mathrm{PER_{CL}} = \omega_{75\%}\left(P^{in,m}_{75\%}\right) + \omega_{100\%}\left(P^{in,m}_{100\%}\right) + \omega_{110\%}\left(P^{in,m}_{110\%}\right)$$

$$= \omega_{75\%}(P_{75\%} + L_{75\%}) + \omega_{100\%}(P_{100\%} + L_{100\%}) + \omega_{110\%}(P_{110\%} + L_{110\%}) \qquad \textbf{(16)}$$

Where:

ω_i = weighting at load point i (equal weighting or $^1/_3$ in this case),

$P_i^{in,m}$ = calculated input power to the motor at load point i (hp),

P_i = the shaft input power to the bare pump at load point i (hp),

L_i = default motor losses at load point i (hp), and

i = load point corresponding to 75, 100, or 110 percent of BEP flow as determined in accordance with the DOE test procedure.

Id.

The part load motor losses for the bare pump would be determined for the bare pump based on a default nominal full load motor efficiency, representative of a motor that is minimally compliant with DOE's electric motor energy conservation standards (or the default minimum motor efficiency for submersible motors), as described in section III.D.1, and the default motor loss curve, as described in section III.D.2. Id.

As presented in section III.B, the PEI_{CL} for a bare pump can then be calculated as the PER_{CL} for a given pump divided by the PER_{STD} for a pump that is minimally compliant with DOE's pump standards sold without controls, as shown in equation (17):

$$PEI_{CL} = \left[\frac{PER_{CL}}{PER_{STD}}\right] \quad \textbf{(17)}$$

Where:

PER_{STD} = the PER_{CL} for a pump of the same equipment class with the same flow and specific speed characteristics that is minimally compliant with DOE's energy conservation standards serving the same hydraulic load (hp). The procedure for determining PER_{STD} is described in detail in section III.B.2.

For bare pumps, DOE proposed establishing the calculation-based approach (method A.1) as the only applicable test procedure, as testing-based methods do not apply to bare pumps because a PEI rating (which includes the efficiency of the motor) cannot be determined based on a test of the bare pump alone.

DOE received no specific comments on the proposed test procedure for bare pumps and is adopting the calculation-based test procedure, as proposed.

b. Calculation-Based Test Method B.1: Pump Sold With a Motor

For pumps sold with motors that either are regulated by DOE's electric motor standards or are submersible motors, DOE proposed to allow the use of the applicable calculation-based method (method B.1), in addition to the testing-based method (method B.2, discussed in section III.E.2.b). In these cases, DOE proposed that the calculation-based test procedure would be similar to that for pumps sold alone (method A.1) except that the represented nominal full load motor efficiency, or losses, would be that of the motor with which the pump is sold when determining PER_{CL}, as opposed to the default nominal full load motor efficiency assumed in the bare pump case. For motors covered by DOE's electric motor standards, DOE proposed that the represented nominal full load motor efficiency be determined in accordance with the DOE electric motor test procedure specified at 10 CFR 431.16 and appendix B to subpart B of part 431 (see section III.D.2) and applicable procedures for determining the represented value (also specified in parts 10 CFR Part 429 and 431). For pumps sold with submersible motors rated using the calculation-based method, the default nominal full load submersible motor efficiency would be determined from Table III.6 (see section III.D.1.b). DOE also reiterated that this calculation-based method would not apply to pumps sold with motors that are not subject to DOE's electric motor standards (except for submersible motors). 80 FR 17586, 17618 (April 1, 2015).

The PEI_{CL} for pumps sold with motors would then be calculated using a similar approach that would be applied to bare pumps shown in equations (16) and (17), above, except that the default part load losses of the motor at each load point would be determined based on the represented nominal full load motor efficiency, as described in section III.D.2. Id.

As previously discussed in section III.B.2, in determining PER_{STD}, DOE proposed to use the electric motor efficiency standards listed at 10 CFR 431.25 for polyphase NEMA Design B motors as the default nominal full load motor efficiency of the minimally compliant pump for pumps sold with motors other than submersible motors. Similarly, for pumps sold with submersible motors, the default nominal full load motor efficiency would be that specified in Table III.6 in section III.D.1.b for both the rated pump model and PER_{STD}. Id.

In the April 2015 pump test procedure NOPR, DOE requested comment on several specific items related to the proposed calculation-based test procedure for pumps sold with applicable motors. Specifically, DOE requested comment on its proposal to determine the part load losses of motors covered by DOE's electric motor energy conservation standards using the represented nominal full load motor efficiency, as determined in accordance with DOE's electric motor test procedure, and the same default motor part load loss curve used in test method A.1. In response, HI commented that it could not comment on this issue. (HI, No. 8 at p. 21) DOE received no additional comments on this proposal.

DOE requested comment on its proposal that pumps sold with motors that are not addressed by DOE's electric motors test procedure (except submersible motors) would be rated based on the testing-based approach, and HI commented that it agrees with this proposal. (HI, No. 8 at p. 21) DOE received no additional comments on this proposal and has determined that no revisions are necessary.

DOE also requested comment on its proposal to determine the PER_{CL} of pumps sold with submersible motors using the proposed default nominal full load efficiency values for submersible motors and to apply the same default motor part load loss curve to the default motor in test method A.1 to the bare pump. HI commented that it agrees with the proposal as long its concerns regarding submersible motor efficiency, as detailed in section III.D.1.b of this final rule, are addressed. (HI, No. 8 at p. 21) DOE received no other comments on this proposal.

Based on the comments received from interested parties, DOE is adopting the proposed test method B.1 for pumps sold with motors covered by DOE's electric motor test procedure. For pumps sold with submersible motors, the default nominal full load submersible motor efficiency values used in the calculation of PER_{CL} and PER_{STD} are the values shown in Table III.7, which are revised based on the input from HI.

c. Calculation-Based Test Method C.1: Pump Sold With a Motor and Continuous Controls

For pumps sold with continuous controls and motors that are either (a) regulated by DOE's electric motor standards for electric motors or (b) submersible motors, DOE proposed, in the April 2015 pumps test procedure NOPR, to allow use of either the applicable calculation-based method (method C.1, discussed in this section III.E.1.c) or the testing-based method (method C.2, discussed in section III.E.2.c). 80 FR 17618–19. The proposed calculation-based approach for pumps sold with motors and continuous controls determines the PEI_{VL} metric, which accounts for the power reduction resulting from reducing speed to achieve a given flow rate, as opposed to throttling. In this case, DOE proposed that the PEI_{VL} would be determined as the PER_{VL} of the given pump divided by the PER_{STD}, where the PER_{STD} would be determined in accordance with the procedures in section III.B.2, and the PER_{VL} would be determined as the weighted average input power to the pump at 25, 50, 75, and 100 percent of BEP flow, as shown in equation (18):

$$PER_{VL} = \omega_{25\%}\left(P_{25\%}^{in,c}\right) + \omega_{50\%}\left(P_{50\%}^{in,c}\right) + \omega_{75\%}\left(P_{75\%}^{in,c}\right) + \omega_{100\%}\left(P_{100\%}^{in,c}\right) \qquad \textbf{(18)}$$

Where:

ω_i = weighting at load point i (equal weighting or ¼ in this case),

$P_i^{in,c}$ = measured or calculated driver power input to the continuous or non-continuous controls at load point i (hp), and i = 25, 50, 75, and 100 percent of BEP flow, as determined in accordance with the DOE test procedure.

Id.

Similar to the calculation-based approaches for bare pumps and pumps sold with motors, the input power to the pump when sold with motors and continuous controls would be determined by adding together the pump shaft input power and the combined losses from the motor and continuous controls at each of the load points. However, in the case of determining PER_{VL} for pumps sold with motors and continuous controls, DOE proposed that only the input power at the 100 percent of BEP flow load point would be determined through testing, and the remaining 25, 50, and 75 percent of BEP flow load points would be calculated based on an assumed system curve. In particular, consistent with CIP Working Group discussions (Docket No. EERE-2013-BT-NOC-0039, No. 107 at pp. 49–50), DOE proposed to use a quadratic reference system curve, which goes through the BEP and an offset on the y-axis, representative of a static head component to the system curve. The reference system curve equation is shown in equation (19) and depicted in Figure III.1:

$$H = \left[0.8 * \left(\frac{Q}{Q_{100\%}}\right)^2 + 0.2\right] * H_{100\%} \qquad \textbf{(19)}$$

Where:

H = the total system head (ft),

Q = the flow rate (gpm),

$Q_{100\%}$ = flow rate at 100 percent of BEP flow (gpm), and

$H_{100\%}$ = total pump head at 100 percent of BEP flow (ft).

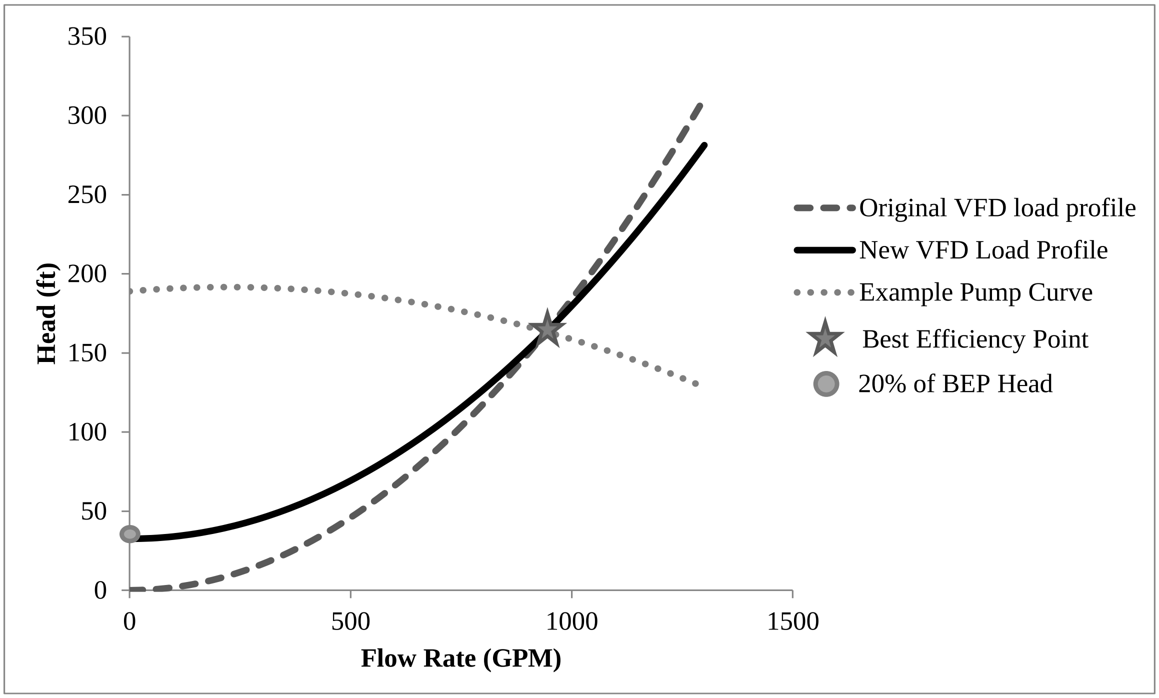

Figure III.1 System Control Curve for Head with Respect to Flow for Pumps Sold with Continuous Controls. Statically offset curve and pure quadratic curve plotted with identical BEP flows. Static offset set at 20 percent of BEP head.

DOE's approach for developing the proposed system curve is discussed in detail in the April 2015 pump test procedure NOPR. Id. at 17619–20.

To determine the pump shaft input power at 25, 50, and 75 percent of BEP flow, DOE proposed to apply the reference system curve discussed in section III.E.1.c and assume that continuous speed reduction is applied to achieve the reduced load points. Specifically, the reduction in pump shaft input power at part loadings was assumed to be equivalent to the relative reduction in pump hydraulic output power assumed by the system curve, as shown in equation (20):

$$P_i = \left(0.8\frac{{Q_i}^3}{{Q_{100\%}}^3} + 0.2\frac{Q_i}{Q_{100\%}}\right) \times P_{100\%} \quad \textbf{(20)}$$

Where:

P_i = shaft input power to the bare pump at load point i (hp),

$P_{100\%}$ = shaft input power to the bare pump at 100 percent of BEP flow (hp),

Q_i = flow rate at load point i (gpm),

$Q_{100\%}$ = flow rate at 100 percent of BEP flow (gpm), and

i = 25, 50, and 75 percent of BEP flow as determined in accordance with the DOE test procedure.

Id. at 17620-21.

Finally, to calculate the PER_{VL} for pumps sold with applicable motors and continuous controls, DOE proposed to apply a separate algorithm for determining the part load losses of the motor and continuous controls together, to account for the additional losses as a result of inefficiencies from the continuous control and increased inefficiencies in the speed-controlled motor due to harmonic distortion. Based on data DOE collected regarding VFD performance, DOE determined that four part load loss equations would be the most appropriate way to represent the combined efficiency of the motor and continuous control as a function of the output power of the motor and, therefore, proposed to use the polynomial expression shown in equation (21) to estimate the aggregate part load losses of motors and continuous controls at each load point:

$$z_i = (a * \left(\frac{P_i}{MotorHP}\right)^2 + b * \left(\frac{P_i}{MotorHP}\right) + c) \quad \textbf{(21)}$$

Where:

z_i = the part load loss factor for the motor and continuous controls at load point i;

a,b,c = coefficients based on motor horsepower, see Table III.9;

P_i = the shaft input power to the bare pump at load point i (hp);

MotorHP = the horsepower of the motor with which the pump is being rated (hp); and

i = 25, 50, 75, and 100 percent of BEP flow as determined in accordance with the DOE test procedure.

Table III.9. Motor and Continuous Control Part Load Loss Factor Equation Coefficients for Equation (21)

	Coefficients for Equation (21)		
Motor Horsepower (hp)	**a**	**b**	**c**
≤5	-0.4658	1.4965	0.5303
>5 and ≤20	-1.3198	2.9551	0.1052
>20 and ≤50	-1.5122	3.0777	0.1847
>50	-0.8914	2.8846	0.2625

The development of DOE’s part load loss factor equations for motors and continuous controls are also described in detail in the April 2015 pumps test procedure NOPR. 80 FR 17586, 17621 (April 1, 2015).

To determine the resultant PEI_{VL} rating for pumps sold with applicable motors and continuous controls and rated based on the calculation-based approach, the PER_{VL} determined based on the reference system curve and default motor and control losses would be divided by the PER_{STD}, determined in accordance with the procedure described in section III.B.2. DOE notes that, although the PER_{VL} of the tested pump only requires the 100 percent of BEP flow load point to be determined experimentally, the full HI 40.6–2014 test would still be required, and the pump hydraulic output power at 75, 100, and 110 percent of BEP flow would still be necessary for determining the PER_{STD} of the given pump. Id. at 17621-22.

In response to DOE's proposed calculation-based approach for pumps sold with application motors and continuous controls, HI commented that it is in agreement with the calculation-based test method for pumps sold with motors and continuous controls, provided that the corrected version of NOPR equation (6) presented at the April 2015 NOPR public meeting is used. (HI, No. 8 at pp. 21–22) HI also specifically indicated that it agrees with the proposed system curve shape, and that it agrees that the curve should go through the statically loaded offset.

Regal Beloit commented that it accepts the structure of the pump energy conservation standards NOPR and the April 2015 pumps test procedure NOPR as presented with respect to motor-drive efficiency testing and evaluation, and encouraged the use of the forthcoming industry standard IEC 61800-9-2 once it is published and at such time as the DOE seeks to revise the pumps test procedure. (Regal Beloit, No. 9 at p. 1) DOE understands that the IEC standard will serve as a 60 Hz version of the 50 Hz European industry standard BS EN 50598. DOE will review the IEC standard once it is available, and may consider it for future rulemaking activity.

DOE received no other comments on this test method, and confirms that the final rule uses the corrected equation for determining the minimum standard pump efficiency presented at the April 2015 NOPR public meeting.

d. Other Calculation Methods for Determination of Pump Performance

In the April 2015 pumps test procedure NOPR, DOE proposed that each bare pump model be physically tested in accordance with the test procedure and that calculations alone could not be used to determine bare pump performance. DOE noted that the calculation-based test procedure for certain applicable pumps already contains provisions for tested bare pump performance to be combined with default or tested performance data regarding the motor or motor with continuous or non-continuous controls to calculate the PER of multiple pump basic models. Therefore, DOE proposed that, beyond the calculations proposed in the April 2015 pumps test procedure NOPR, DOE would not permit use of other algorithms or alternative efficiency determination methods to determine the rated performance of covered pumps or pump components (i.e., motors or controls). 80 FR 17586, 17622-23 (April 1, 2015).

DOE requested comment on its proposal to require testing of each individual bare pump as the basis for a certified PEI_{CL} or PEI_{VL} rating for one or more pump basic models. DOE also requested comment on its proposal to limit the use of calculations and algorithms in the determination of pump performance to the calculation-based methods proposed in the NOPR. HI commented that it agrees with these proposals. (HI, No. 8 at p. 22) DOE received no additional comments on these proposals and, consistent with the comments submitted by HI, is adopting such calculation methods as discussed in this section III.E.1 in this final rule.

2. Testing-Based Methods

Testing-based methods directly measure the input power to the motor, continuous control, or non-continuous control at the load points of interest (i.e., 75, 100, and 110 percent of BEP flow for uncontrolled pumps and 25, 50, 75, and 100 percent of BEP flow for pumps sold with a motor and speed controls). As such, as discussed previously, these methods cannot be applied to bare pumps. In addition, these test methods are the only test methods applicable to pumps sold with motors that are not addressed by DOE's electric motor test procedure (except submersible motors) or that are sold with non-continuous controls and are an optional procedure for all pumps sold with motors or motors with continuous controls.

The following sections describe DOE's proposals, any comments received from interested parties, and the final test provisions DOE is adopting in this final rule on the following topics:

- how to determine BEP for pumps rated using the testing-based method (section III.E.2.a),
- the testing-based approach for pumps sold with motors (method B.2; described in section III.E.2.b), and
- the testing-based approach for pumps sold with motors and continuous or non-continuous controls (method B.3; described in section III.E.2.c).

a. The Best Efficiency Point for Pumps Testing Using Testing-Based Methods

In the April 2015 pumps test procedure NOPR, DOE noted that when testing some pumps using testing-based methods, it is not possible to determine BEP as a ratio of pump input power over pump hydraulic power unless additional measurements are made of bare pump performance or pump shaft input power, in addition to input power to the motor. See section III.C.2.d. Specifically, in the case of pumps sold with motors or motors with continuous or non-continuous controls measured using testing-based methods, DOE noted that input power to the pump shaft is not measured directly in the proposed test procedure. As such, DOE proposed that the BEP for such pumps be determined using a similar procedure to that discussed in section III.C.2.d for calculation-based methods; however, BEP would be determined using the maxima of what is typically known as overall efficiency (i.e., the input power to the driver or continuous control, if any, divided by the pump hydraulic output power at the nominal speed), rather than pump efficiency. 80 FR 17586, 17623 (April 1, 2015).

DOE requested comment on its proposal to require manufacturers to determine BEP for pumps rated with a testing-based method by using the ratio of input power to the driver or continuous control, if any, over pump hydraulic output. DOE also requested input on the degree to which this method may yield significantly different BEPs from the case in which BEP is determined based on pump efficiency. HI commented that BEP can only be determined when testing the bare pump. HI also indicated that determining BEP through a wire-to-water (i.e., testing-based) method will cause the manufacturers to have to test each motor configuration sold with the bare pump, increasing the burden. HI recommended that the manufacturer be given the option to determine BEP by testing as a bare pump or by testing using a wire to water test. HI also recommended that BEP be instead defined as the pump hydraulic power operating point consisting of both flow and head conditions that result in the maximum efficiency of the certified unit. (HI, No. 8 at pp. 22–23)

After review, DOE has determined that the HI proposal would yield different efficiency ratings for the same pump. In response to HI's comment, DOE notes that DOE initially proposed that the BEP when applying the testing-based methods would be based on the overall efficiency in order to reduce burden when conducting testing. That is, when testing a pump in accordance with the testing-based method, DOE proposed that the overall efficiency would be used to determine pump efficiency so that the pump shaft input power would not have to be separately determined, since measurements of pump shaft input power are not otherwise needed when conducting the test procedure. If DOE were instead to specify that BEP be determined based on the pump efficiency only, pumps tested using the testing-based approaches would either need to have additional instrumentation installed (e.g., a torque sensor) to measure pump shaft input power or, in some cases, would require duplicative testing of the pump with a calibrated motor if a torque sensor could not be inserted between the bare pump and motor based on the pump design. For example, ESCC and VTS pumps would not be able to be tested using the testing-based methods to determine BEP based on pump efficiency in the same test, unless a calibrated motor with the same characteristics as the motor with which the pump model was to be distributed in commerce was used.

In response to HI's concern regarding the increased burden of determining the BEP based on overall efficiency, DOE finds this statement to be erroneous, since the determination of BEP based on overall efficiency would only be required for the testing-based approaches and the testing-based approaches already require each basic model to be tested. Under the proposed approach, no incremental testing would be necessary. To the extent that manufacturers wish to use the calculation-based methods to determine the PEI of applicable pumps, the BEP of the bare pump, based on pump efficiency, must be used. However, these data are irrelevant to determining the PEI of pumps under the testing-based approach, since the two methods are mutually exclusive. That is, the PEI of a given pump cannot be determined via both calculation-based and testing-based approaches. DOE has ensured that this is clear in the regulatory text included in this final rule.

Regarding HI's proposal to optionally allow manufacturers to use either pump efficiency or overall efficiency, DOE believes that such an approach could potentially result in variability in the BEP, and thus PEI, for the same pump model. This is unacceptable since each pump model can have only one certified PEI value associated with it and that value must be repeatable and consistent among test facilities.

DOE believes that the approach proposed in the April 2015 pumps test procedure NOPR will result in representations that are more straightforward and consistent, as well as less burdensome, for those pumps rated using the testing-based approach. As such, DOE is adopting, in this final rule, the approach proposed in the April 2015 pump test procedure NOPR to determine the BEP of pumps rated using the testing-based approach based on overall efficiency, as opposed to pump efficiency.

Regarding HI's comment that BEP should be determined as the load point associated with maximum efficiency, which consists of both head and flow points, DOE acknowledges HI's comments and agrees that the BEP for each pump represents the flow and head points representing maximum efficiency at full impeller diameter. In particular, DOE notes that DOE's definition of BEP, as adopted in this final rule, specifies BEP with respect to a load point, consisting of both flow and head conditions. However, in this test procedure final rule, DOE in general refers to BEP flow, since DOE's specified load points are characterized with respect to BEP flow only. DOE understands that the head and flow of a given pump, at full impeller diameter and without throttling, are inextricably linked, so it is not necessary to independently account for and specify both parameters. That is, for example, by specifying the flow at 100 percent of BEP, the power calculated at that load point will, necessarily, also be reflective of head at 100 percent of BEP flow, since the data are all based on the same curve. It is not possible to determine the power input at, for example, 50 percent of BEP flow and 100 percent of BEP head without throttling the pump, trimming the impeller, or otherwise physically altering the tested equipment or test set-up such that the data generated would no longer be reflective of the pump model being tested. As such, DOE does not believe that any additional specifications or clarifications regarding the BEP load point are necessary in the pumps test procedure.

b. Testing-Based Test Method B.2: Pump Sold With a Motor

For pumps sold with motors that are not regulated by DOE's electric motor standards (except for submersible motors), DOE proposed that use of the testing-based method B.2, discussed in this section III.E.2.b, would be required because the nominal full load efficiency of the motor, as determined using a specific standardized procedure, is not available for those motors. For pumps sold with motors subject to DOE's electric motor standards or submersible motors, the testing-based approach discussed in this section III.E.2.b would be optional.

In the April 2015 pumps test procedure NOPR, DOE also proposed that, for pumps sold with motors, the PEI_{CL} could be determined by wire-to-water testing, as specified in HI 40.6–2014, section 40.6.4.4. In this case, the PER_{CL} would become an average of the measured power input to the motor at the three specified load points, as shown in equation (22):

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

$$= \omega_{75\%}\left(P_{75\%}^{in,m}\right) + \omega_{100\%}\left(P_{100\%}^{in,m}\right) + \omega_{110\%}\left(P_{110\%}^{in,m}\right) \quad \textbf{(22)}$$

Where:

ω_i = weighting at load point i (equal weighting or $^1/_3$ in this case),

$P_i^{in,m}$ = measured or calculated driver power input to the motor at load point i (hp), and

i = load point at 75, 100, or 110 percent of BEP flow as determined in accordance with the DOE test procedure.

80 FR 17586, 17623 (April 1, 2015).

DOE received no comments on the proposed testing-based approach for pumps sold with motors and, as such, is adopting the provisions discussed in the April 2015 pumps test procedure NOPR with no changes.

c. Testing-Based Test Method C.2: Pump Sold With a Motor and Speed Controls

For pumps sold with non-continuous control-equipped motors that are either (1) regulated by DOE's electric motor standards for electric motors or (2) submersible motors, as defined in section III.E.1.c, DOE proposed in the April 2015 pumps test procedure NOPR that the calculation-based method C.1 would not be applicable because these controls are not able to follow the reference system curve described in section III.E.1.c. Instead, pumps sold with non-continuous controls would have to be tested using the testing-based method C.2. For pumps sold with motors not regulated by DOE's electric motor standards (excluding submersible motors) that are equipped with either continuous or non-continuous controls, DOE also noted that only these testing-based methods (method C.2) would apply, as is the case for pumps sold with motors not regulated by DOE's electric motor standards (excluding submersible motors) without controls (discussed in section III.E.2.b). 80 FR 17586, 17627 (April 1, 2015).

For pumps sold with continuous controls and motors that are (1) regulated by DOE's electric motor standards for electric motors or (2) submersible motors, the testing-based approach discussed herein (method C.2) would be optional, and such pumps may also be tested under the calculation-based approach, as discussed in section III.E.1.c. Id.

Regarding the specific procedures contained in the testing-based approach for pumps sold with motors and continuous or non-continuous controls, DOE proposed that the PEI_{VL} may be determined by wire-to-water testing, based on the procedure specified in HI 40.6, section 40.6.4.4, except that the input power:

- is the "driver input power" defined in table 40.6.2.1 of HI 40.6–2014 and referenced in table 40.6.3.2.3, section 40.6.4.4, and section 40.6.6.2,
- refers to the input power to the continuous or non-continuous control, and
- is determined in accordance with the tolerances and requirements for measuring electrical power described in section III.C.2.e.

80 FR 17623–24.

DOE clarified that, with the proposed approach, pump manufacturers would determine the BEP of the pump, inclusive of motor and continuous or non-continuous controls, as described in section III.E.2.a, and then adjust the operating speed of the motor and the head until the specified head and flow conditions are reached (i.e., 25, 50, and 75 percent of BEP flow and the associated head pressures determined by the reference system curve in section III.E.1.c). To ensure this method C.2 results in consistent and repeatable ratings, DOE also proposed tolerances around each load point of 10 percent about (i.e., above and below) the target flow and head load points defined on the reference system curve for each pump. Similarly, DOE also proposed that the measured data would be extrapolated to the exact load points specified by the reference system curve using the following equation (23):

$$P_i^{in,c} = \left(\frac{H_{sp,i}}{H_{M,j}}\right)\left(\frac{Q_{sp,i}}{Q_{M,j}}\right)P_{M,i} \qquad \textbf{(23)}$$

Where:

P_i = the corrected driver power input to the continuous or non-continuous controls at load point i (hp),

$H_{sp,i}$ = the specified total system head at load point i based on the reference system curve (ft),[70]

$H_{M,j}$ = the measured total system head at load point j (ft),

$Q_{sp,i}$ = the specified total system flow rate at load point i based on the reference system curve (gpm),

$Q_{M,j}$ = the measured total system flow rate at load point j (gpm),

$P_{M,j}$ = the measured shaft input power to the bare pump at load point j,

i = specified load point at 25, 50, 75, or 100 percent of BEP flow as determined in accordance with the DOE test procedure, and

j = measured load point corresponding to specified load point i.

Id. at 17624–25.

Under DOE's proposed approach, the PER would become the mean of the measured power input to the continuous or non-continuous control at the four specified load points based on the assumed system curve (as in method C.1), as shown in equation (24):

$$PER_{VL} = \sum_{i=25\%,50\%,75\%,100\%} (\omega_i P_i^{in,c})$$

$$= \omega_{25\%}\left(P_{25\%}^{in,c}\right) + \omega_{50\%}\left(P_{50\%}^{in,c}\right) + \omega_{75\%}\left(P_{75\%}^{in,c}\right) + \omega_{100\%}\left(P_{100\%}^{in,c}\right) \qquad \textbf{(24)}$$

[70] DOE notes that in the April 2015 pumps test procedure NOPR, DOE proposed to define the tested and "reference" head and flow values using the subscript "T" for tested and "R" for rated (e.g., H_R, H_T, Q_R, Q_T). DOE notes that Table 40.6.2.2b of HI 40.6-2014 provides a list of subscripts for use in applying the HI 40.6-2014 test method. Specifically, Table 40.6.2.2b defines the subscript "sp" as denoting "specified" values and the subscript "M" as denoting measured values. For the sake of clarity and continuity, in this final rule, DOE is adopting subscripts consistent with the defined HI nomenclature.

Where:

ω_i = weighting at load point i (equal weighting or ¼ in this case),

$P_i^{in,c}$ = measured or calculated driver power input to the continuous or non-continuous controls at load point i (hp), and

i = load point at 25, 50, 75, or 100 percent of BEP flow, as determined in accordance with the DOE test procedure.

Id. at 17625.

In the April 2015 pumps test procedure NOPR proposal, DOE also noted that some pumps are sold with non-continuous controls, such as multi-speed motors, that are not able to follow the reference system curve directly at all load points. For example, in the case of a pump sold with a two-speed motor, the pump will operate at full speed (i.e., the nominal speed) for some of the load points and reduced speed at the other load points, as shown in Figure III.2.

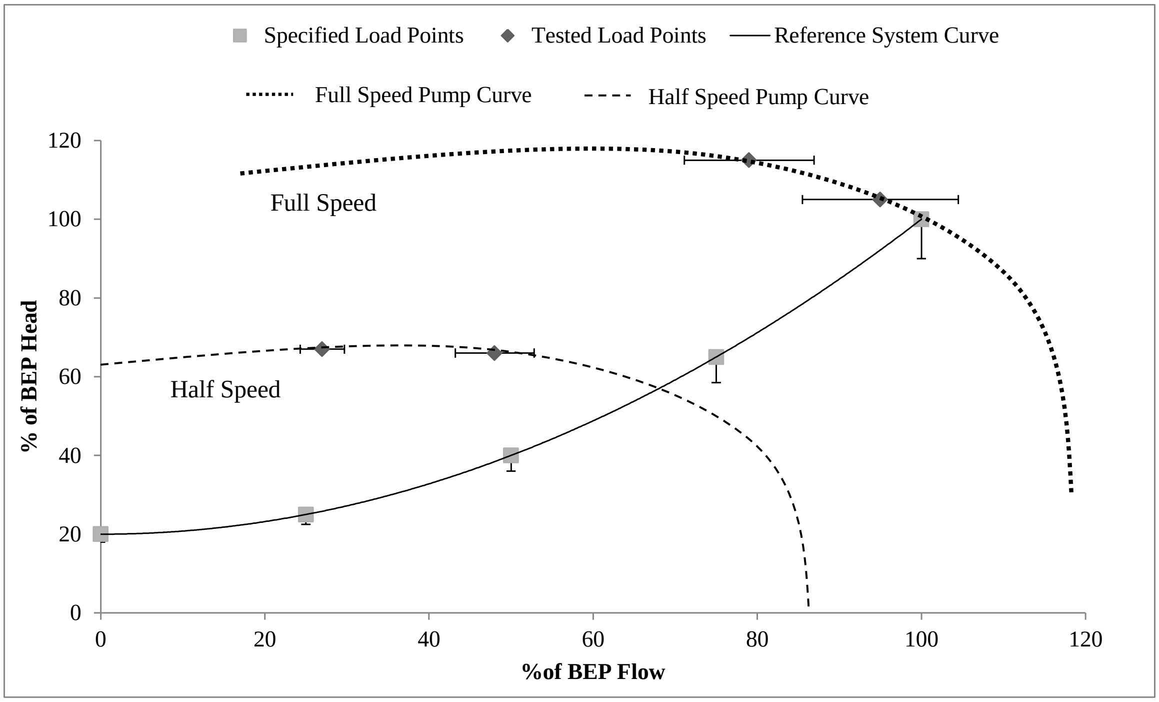

Figure III.2 Load Points Compared to Reference System Curve and Full Speed Pump Curve for a Theoretical Two-Speed Motor.

For pumps sold with non-continuous controls, DOE proposed to modify this testing-based method C.2 for pumps sold with motors and continuous or non-continuous controls to specify that the head measurements associated with each of the specified flow points would not have to be achieved within 10 percent of the specified head, as described by the reference system curve—only the flow rate would need to be achieved within 10 percent of the specified value. Id. at 17626. Instead, DOE proposed to require that the measured pump total head corresponding to the 25, 50, 75 and 100 percent of BEP flow points could not be lower than 10 percent below that defined by referenced system curve. DOE also proposed that, in this case, the measured head and flow rate would not be corrected to the reference system curve. Instead, the tested load points would be used directly in further calculations of PEI_{VL}. Id.

DOE requested comment on the proposed testing-based method for pumps sold with motors and continuous or non-continuous controls, as well as the proposed testing-based method for determining the input power to the pump for pumps sold with motors and non-continuous controls. In addition, DOE requested comment on any other type of non-continuous control that may be sold with a pump and for which the proposed test procedure would not apply.

HI commented that it agrees with the optional testing-based methods, but also indicated that any pump sold with an ON/OFF control should be tested or calculated using a PEI_{CL} method. (HI, No. 8 at p. 23) DOE agrees with HI that ON/OFF switches do not constitute a type of continuous or non-continuous control for which the calculation-based or testing-based methods (C.1 and C.2, respectively) or the PEI_{VL} metric, would be applicable. Consistent with the April 2015 pumps test procedure NOPR section III.A.1.a and public meeting slide 45, DOE has revised Table 1 in appendix A accordingly to clarify that (1) the calculation-based and testing-based methods to determine PEI_{VL} apply to pumps sold with motors and continuous or non-continuous controls only; whereas, (2) the test methods for pumps sold with motors (methods B.1 and B.2) apply to pumps sold with motors and controls other than continuous and non-continuous controls.

F. Representations of Energy Use and Energy Efficiency

As noted previously, manufacturers of any pumps within the scope of the pump test procedure will be required to use the test procedure established in this rulemaking when making representations about the energy efficiency or energy use of their equipment. Specifically, 42 U.S.C. 6314(d) provides that "[n]o 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."

In the April 2015 pumps test procedure NOPR, DOE noted that performing the proposed test procedure for pumps requires a key component (C-value) that is being addressed through the parallel standards rulemaking for pumps (Docket No. EERE-2011_BT-STD-0031). 80 FR 17586, 17628 (April 1, 2015). Because of this dependency, DOE clarified that manufacturers of equipment that are addressed by this test procedure and any applicable standards that DOE may set would have 180 days after the promulgation of those standards to begin using the DOE procedure.

With respect to representations, generally, DOE stated its understanding that manufacturers often make representations (graphically or in numerical form) of energy use metrics, including pump efficiency, overall (wire-to-water) efficiency, bowl efficiency, driver power input, pump power input (brake or shaft horsepower), and/or pump power output (hydraulic horsepower) and may make these representations at multiple impeller trims, operating speeds, and number of stages for a given pump. DOE proposed in the April 2015 pumps test procedure NOPR to allow manufacturers to continue making these representations. Id.

DOE also proposed that any representations of PEI and PER must be made in accordance with the DOE test procedure, and there may only be one PEI or PER representation for each basic model. In other words, representations of PEI and PER that differ from the full impeller PEI and PER cannot be made at alternate speeds, stages, or impeller trims. Additionally, if the PEI and PER for a basic model is rated using any method other than method A.1, "bare pump with default motor efficiency and default motor part load loss curve," such a basic model may not include individual models with alternate stages or impeller trims.

If a manufacturer wishes to make unique representations of PEI or PER based on a trimmed impeller, the manufacturer must certify the trimmed impeller as a separate basic model. In such a case, the "trimmed impeller" being rated would become the "full impeller" for the new basic model (i.e., the maximum diameter impeller distributed in commerce for that pump model) (see section III.A.1.c). 80 FR 17586, 17628 (April 1, 2015).

In response to DOE's language regarding representations in the April 2015 pumps test procedure NOPR, HI stated its concern with the somewhat vague language used around 42 U.S.C. 6314(d) prohibited representation. HI emphasized that it is imperative that pump manufacturers be allowed to continue using pre-existing efficiency curves and sizing software that is used directly by end users and distributors to purchase pumps. HI noted its interpretation that the following text: "Manufacturers often make these representations at multiple impeller trims, operating speeds, and number of stages for a given pump. DOE proposes to allow manufacturers to continue making these representations." indicates that existing performance and efficiency data can continue to be used and that only representations of PER and PEI fall under [the requirements of] 42 U.S.C. 6314(d) "Prohibited Representation." HI requested that DOE clearly articulate in the final rule that prohibited representation under 42 U.S.C 6314(d) applies only to PER and PEI representations. (HI, No. 8 at p. 1)

In response to HI's comment regarding the nature of representations manufacturers are allowed to make regarding the performance of their equipment under 42 U.S.C. 6314(d), DOE reiterates that, beginning 180 days after publication of this final rule in the Federal Register, all representations regarding PER_{CL} and PER_{VL} must be made in accordance with the DOE test procedure. Similarly, all representations regarding PEI_{CL} and PEI_{VL} must be made in accordance with the DOE test procedure beginning 180 days after publication of a final rule in the Federal Register that sets C-values (i.e., a final rule in the parallel energy conservation standards rulemaking). However, regarding other measures of energy use, energy efficiency, or related performance metrics for pumps, DOE clarifies that such representations must be made using methods that will generate values consistent with the DOE test procedure, as finalized in this final rule. DOE acknowledges that manufacturers have large amounts of pre-existing data that they currently use to market and make representations about the performance of their equipment and that regenerating all of this data within the 180 day timeframe would be burdensome. As such, manufacturers may continue to use such data to make representations about the performance of applicable pump models after the 180 day timeframe, provided manufacturers are confident that the values are consistent with those that would be generated under the adopted test procedure.

In the April 2015 NOPR public meeting, the EEAs noted that it would be helpful if DOE could have its certification materials available prior to the compliance date so that manufacturers can make early representations of PEI. (EEAs, NOPR public meeting transcript, No. 7 at pp. 191–192) The EEAs also noted that it would be helpful for all the fields in the certification report to show up in the database, or that they would determine which items the utility programs would need. (EEAs, NOPR public meeting transcript, No. 7 at pp. 206–207) DOE discusses compliance certification reporting in the parallel energy conservation standards rulemaking, and has considered the stakeholder comments in that rule.

G. Sampling Plans for Pumps

DOE provides in subpart B to 10 CFR part 429 sampling plans for all covered equipment. The purpose of these sampling plans is to provide uniform statistical methods for determining compliance with prescribed energy conservation standards and for making representations of energy consumption and energy efficiency on labels and in other locations such as marketing materials. In the April 2015 pumps test procedure NOPR, DOE proposed that, for pumps, the same statistical sampling plans used for other commercial and industrial equipment would be applicable and proposed to add the sampling plan to 10 CFR 429.59. 80 FR 17586, 17628-29 (April 1, 2015).

Under the proposal, DOE proposed that a sample of sufficient size must be randomly selected and tested to ensure compliance and that a minimum of two units must be tested to certify a basic model as compliant. DOE also proposed to apply the same statistical sampling procedures, including the confidence limit and derating factor, that are applicable to many other types of commercial and industrial equipment, as DOE believes equipment variability and measurement repeatability associated with the measurements proposed for rating pumps are similar to the variability and measurement repeatability associated with energy efficiency or consumption measurement required for other commercial equipment. Id.

Finally, DOE proposed that DOE would determine compliance in an enforcement matter based on the arithmetic mean of a sample not to exceed four units. Id.

DOE received no comments on this proposal. However, upon reviewing the April 2015 pump test procedure NOPR proposals, DOE identified several provisions that require clarification to ensure that DOE's certification and enforcement provisions are clear and consistent.

First, in the April 2015 pumps test procedure NOPR, the equations for the upper confidence limit (UCL) and lower confidence limit (LCL) in section 429.60 both referenced a confidence limit of 0.95. 80 FR 17586, 17640 (April 1, 2015). However, the UCL and LCL were proposed to be divided by a de-rating factor of 1.01 and 0.99, respectively. Id. DOE notes that the confidence limit of the t-statistic and the de-rating factor in the denominator, collectively, are intended to capture the likely variability in pump testing resulting from the allowable test tolerances and instrument accuracy (discussed in sections III.C), lab-to-lab variability, and manufacturing tolerances contained within each model. In the April 2015 pumps test procedure NOPR, DOE had proposed a confidence limit of 99 percent, expecting a 95 percent confidence limit would exceed the amount of variability in PEI that would occur in pump ratings. Specifically, because PEI is an indexed value, with values that range from zero to one, this decreases the amount of variability that may occur in each individual measurement.

DOE received no comments from interested parties in response to the proposal in the April 2015 pumps test procedure NOPR. However, DOE reevaluated the April 2015 pumps test procedure NOPR proposal and determined that the resultant values may yield overly conservative results that would effectively require such pumps to meet a more stringent standard than that considered in the associated pumps energy conservation standards rule (Docket No. EERE-2011-BT-STD-0031). Therefore, in this final rule, DOE is correcting the confidence limit and derating factor adopted in this final rule to better reflect the likely variability in test results expected to result from the pumps test procedure, lab-to-lab variability, and manufacturing tolerances. Specifically, for the purpose of regulating pumps, a confidence limit of 0.95 and de-rating factor of 1.05 or 0.95 is required due to the combined impacts of test tolerances, experimental variability in conducting the test procedure, and manufacturing variability for this equipment. That is, given the likely variation of measured PEIs within a sample of pump units of the same model, a confidence limit of 0.95 is necessary to ensure that the statistical requirements in the sampling plan for pumps are consistent with the magnitude of the variance between tested units within a sample resulting from manufacturing tolerances and experimental uncertainty inherent in the test procedure. Therefore, DOE is adopting a confidence limit of 0.95 and de-rating factors of 1.05 and 0.95 as applicable to pumps in this test procedure final rule.

Also, regarding testing pumps for enforcement purposes, DOE is clarifying, in this final rule, the procedure for determining BEP when the "expected BEP" may not be known to DOE. As discussed in section III.C.2.d, the procedure for determining BEP described in section 40.6.5.5.1 of HI 40.6–2014 requires that the flow points are to be 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP of the pump model and that if the BEP rate of flow is displaced by more than 5 percent, the test must be repeated. In the case of enforcement testing, DOE will follow the same procedure as manufacturers in determining the BEP of the pump. In this final rule, DOE is clarifying that DOE will use the volume rate of flow (flow rate) at BEP and nominal speed certified by the manufacturer for that pump model as the expected BEP when performing the BEP test. In the case that the BEP rate of flow is more than 5 percent displaced from the certified value, DOE will also retest the pump as required by the test procedure. However, if the retested BEP rate of flow is still more than 5 percent displaced from the manufacturer's certified value, DOE will use the mean of the tested values as the volume rate of flow (flow rate) at BEP and nominal speed in subsequent calculations when determining the PEI for that model.

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 OMB.

B. Review under the Regulatory Flexibility Act

The Regulatory Flexibility Act (5 U.S.C. 601, et seq.) requires preparation of a regulatory flexibility analysis for any rule that by law must be proposed for public comment, unless the agency certifies that the rule, if promulgated, will 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 (August 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. 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 today's final rule, which establishes new test procedures for pumps, under the provisions of the Regulatory Flexibility Act and the procedures and policies published on February 19, 2003. DOE concludes that the final rule DOE is adopting will not result in a significant impact on a substantial number of small entities. The factual basis set forth in the following sections.

1. The Need for, and Objectives of, Today's Rule

While DOE is currently evaluating whether to establish energy conservation standards for pumps, DOE must first establish a test procedure that measures the energy use, energy efficiency, or estimated operating costs of a given type of covered equipment before establishing any new energy conservation standards for that equipment. See, generally, 42 U.S.C. 6295(r) and 6316(a). To fulfill these requirements, DOE is establishing the test procedure for pumps, described in this final rule, concurrent with its ongoing energy conservation standards rulemaking for this equipment. See Docket No. EERE-2011-BT-STD-0031.

In this test procedure, DOE prescribes test methods for measuring the energy consumption of certain pumps, inclusive of motors and controls (continuous or non-continuous), if they are included with the pump when distributed in commerce. In addition, this final rule establishes a new subpart Y to part 431 of Title 10 of the Code of Federal Regulations that contains DOE's new test procedure for pumps, as well as definitions pertinent to establishing the scope of pumps to which the adopted test procedure is applicable. This final rule also contains sampling plans for pumps for the purposes of demonstrating compliance with any energy conservation standards that DOE adopts.

DOE's test procedure contains methods to determine the energy consumption for all equipment for which this test procedure applies using either calculation-based methods and/or testing-based methods. While both methods include some amount of testing and some amount of calculation, the terms "calculation-based" and "testing-based" are used to distinguish between methods in which the input power to the pump is determined either by (a) measuring the bare pump shaft input power[71] and calculating efficiency, or losses, of the motor and any continuous control[72] (i.e., calculation-based method) or (b) measuring the input power to the driver,[73] or motor, and any continuous or non-continuous controls[74] for a given pump directly (i.e., testing-based method). As such, the test procedure includes measurements and calculations of the produced hydraulic power, pump shaft input power, electric input power to the motor, and electrical input power to the continuous or non-continuous controls, as applicable, which are substantially based on the test methods contained in the industry test standard HI Standard 40.6–2014, "Methods for Rotodynamic Pump Efficiency Testing," ("HI 40.6–2014"), with slight modifications as noted in section III.C.2.

[71] The term "pump shaft input power" is referred to as "pump power input" in HI 40.6-2014. The term "pump shaft input power" is used synonymously with that term in this document.

[72] DOE notes that for non-continuous controls, as defined in section III.E.1.c, PEI_{VL} can only be determined using a "testing-based" method. If a calculation-based method is desired, the pump would instead be rated as a pump sold with a motor and without speed controls using the PEI_{CL} metric. See section III.E.1.c for further discussion.

[73] The input power to the driver is referred to as "driver power input" in HI 40.6-2014. The term "input power to the driver" is used synonymously with that term in this document.

[74] In the case that a pump is sold with a motor equipped with either continuous or non-continuous controls and is rated using the testing-based method, the input power to the pump would be determined as the input power to the continuous or non-continuous control. See section III.E.2.c

This test procedure final rule also contains requirements regarding (1) the characteristics, categories, and configurations of pumps to which the adopted test procedure is applicable; (2) the specific manner in which pumps must be tested to determine any applicable representations regarding the performance of pumps subject to the test procedure; and (3) the number of pump units that must be tested to determine the representative value for each basic model. As noted in the April 2015 pump test procedure NOPR and further elaborated in section III.F, DOE's new pumps test procedure requires a key component (C-value) that is being addressed through the parallel standards rulemaking for pumps (Docket No. EERE-2011_BT-STD-0031). 80 FR 17586, 17628 (April 1, 2015). As such, the use of this test procedure as the basis for any representations regarding the energy efficiency or energy use of pumps would not be required until 180 days after the publication of any energy conservation standards final rule in the Federal Register, Therefore, DOE notes that the test methods, definitions, and sampling plans contained in this final rule do not introduce any incremental burden to any manufacturers, since the use of such test methods is not required by this test procedure final rule by itself. That is, any burden associated with testing pumps in accordance with the requirements of this test procedure final rule is not be required until the promulgation of any energy conservation standards final rule for pumps. On this basis, DOE maintains that this final rule has no incremental burden associated with it and a final regulatory flexibility analysis is not required.

While DOE maintains that this final rule has no incremental burden associated with it when viewed as a stand-alone rulemaking, DOE recognizes that pump energy conservation standards are currently being considered in an associated rulemaking (Docket No. EERE-2011-BT-STD-0031) and may be proposed or promulgated in the near future. Therefore, to consider the aggregate impacts of developing certified ratings for applicable pump models for the purposes of making representations regarding the energy use of such equipment or certifying compliance to DOE under any future energy conservation standards, DOE is also estimating the full burden of conducting the testing required by this test procedure final rule for each pump model. Therefore, while such is not required yet, DOE is presenting the results from conducting the regulatory flexibility analysis to develop estimates of the costs associated with testing equipment consistent with the requirements of this test procedure final rule, as would be required to certify compliance with the potential energy conservation standard. DOE presents the results of such analysis in the following sections.

However, DOE is not determining the significance of that burden with respect to manufacturers' financial situation or status as a small entity. As the use of the testing requirements contained in this final rule is contingent upon the energy conservation standards rulemaking, DOE is analyzing the effect of the combined burden associated with both the test procedure and energy conservation standard rulemakings in the manufacturer impact analysis performed as part of the energy conservation standard rulemaking (see docket EERE-2011-BT-STD-0031). The costs described in the following subsections are referenced in the manufacturer impact analysis in the pumps energy conservation standard rulemaking to estimate the burden associated with testing. However, DOE reiterates that the estimates provided in this test procedure regulatory flexibility analysis serve only to provide information about the possible burden manufacturers may incur while testing pumps using this DOE test procedure; they do not represent actual burden incurred by the industry as there is no incremental burden associated with this test procedure final rule until and unless the associated pumps energy conservation standard final rule is published.

2. Significant Issues from Interested Parties in Response to IRFA

Within the April 2015 pumps test procedure NOPR, DOE conducted an initial regulatory flexibility analysis (IRFA). 80 FR 17586, 17629-33 (April 1, 2015). In response to DOE's April 2015 pumps test procedure NOPR estimate of testing burden, DOE received written and verbal comments at the April 2015 NOPR public meeting, as well as throughout the comment period. Comments related to the potential burden include comments related to potential anticompetitive effects of the proposed test procedure; cost of test facility(s); labor costs; quantity of manufacturers potentially affected; and manufacturer sales to assess burden. In this final rule, DOE addresses these comments and presents a revised assessment of potential burden related to test procedure final rule.

Anticompetitive Effects of Burden and Expense

Consistent with DOE's requirements to comply with section 32(c) of the Federal Energy Administration Act of 1974, as amended by the Federal Energy Administration

Authorization Act of 1977 (15 U.S.C. 788; see section IV.L), DOE is required to consult with the Attorney General and the Chairman of the Federal Trade Commission (FTC) concerning the impact of the proposed test procedure on competition in the pumps industry. The U.S. Department of Justice (DOJ) reviewed the April 2015 pumps test procedure NOPR, attended the April 2015 NOPR public meeting, and consulted with members of the industry in preparing their comments and conclusions regarding any anticompetitive effects of the pumps test procedure. In response to the proposed test procedure, DOJ commented that it is not able to determine whether or not the proposed test procedure (or associated energy conservation standard) will lessen competition within the industry. However, DOJ noted that it is concerned about the possibility of anticompetitive effects resulting from the burden and expense of compliance. (DOJ, No. 14 at p. 2)

In this final rule, DOE reviews the potential burden and expense related to testing, but does not analyze the potential effects on competition. However, DOE notes that it has taken steps, in the test procedure adopted in this final rule to minimize burden on manufacturers related to testing and rating equipment in accordance with such procedures.

Burden of Test Facility(s)

In the April 2015 pumps test procedure NOPR, DOE estimated the burden to manufacturers associated with performing testing in accordance with the proposed test procedure. 80 FR 17586, 17629-33 (April 1, 2015). DOE estimated that in order to determine the performance of any covered pump models for the purposes of making representations or certifying compliance under any future energy conservation standards for pumps, each manufacturer would have to either (a) have the units tested in-house or (b) have the units tested at a third party testing facility. In addition, if the manufacturer elected to test pumps in-house, each manufacturer would have to undertake the following burden-inducing activities:

1) construct and maintain a test facility that is capable of testing pumps in compliance with the test procedure, including acquisition and calibration of any necessary measurement equipment, and
2) conduct the DOE test procedure on two units of each covered pump model.

Id.

Because pumps are newly regulated equipment and there are no existing testing requirements for pumps, the capabilities of existing testing facilities may vary widely from one manufacturer to another. In the April 2015 pumps test procedure NOPR, DOE based it's assessment of testing burden on the conservative assumption that pump manufacturers would have no existing testing infrastructure and would have to bear the full cost of constructing a new testing facility generally capable of conducting testing in accordance with the proposed test procedure. DOE estimated the capital cost of constructing the two types of facilities: a facility equipped to perform the calculation-based test methods (described in section, III.E.1), which varied between $91,000 and $277,000, and a facility equipped to perform the testing-based test methods (described in section, III.E.2), which varied between $72,000 and $213,000. DOE amortized these capital costs to determine an annual payment amount over an estimated 7-year loan period because DOE's research indicated this was the typical loan period for pump manufacturers. DOE's final calculations regarding the cost of constructing a test lab assumed that the majority of pump models would be certified based on the bare pump configuration and subsequent ratings for the same bare pump sold with any number of applicable motors and continuous controls could be generated using the calculation-based approach. In addition, DOE estimated the ongoing cost of testing between $161.61 and $430.96 per unit, plus calibration activities of $1,241.67 per year. 80 FR 17586, 17632 (April 1, 2015) Based on these assumptions, DOE estimated the amortized total burden associated with the test procedure ranged between $61,000 and $221,000 annually for small manufacturers affected by this rule. Id.

DOE requested specific comments and feedback on a number of assumptions made in the April 2015 pumps test procedure NOPR regulatory flexibility analysis. Regarding the cost of constructing a test facility capable of performing the test procedure presented in the April 2015 pumps test procedure NOPR, HI stated that the estimates of materials and costs to build a pump testing facility as presented are greatly underestimated and would be in excess of $1 million. HI indicated that DOE's facility description leaves out many expensive machines and other equipment that would be required for this testing. (HI, No. 0008 at pp. 24-25)

DOE disagrees with the comments from HI regarding the cost of the testing facility and the effect of burden on manufacturers and the industry. DOE notes that, in the April 2015 pumps test procedure NOPR initial regulatory flexibility analysis (IRFA), DOE used the most burdensome assumptions to estimate the burden associated with complying with the test procedure, resulting in estimates lower than the $1 million HI suggested. DOE notes that the estimated costs in the IRFA were based on the construction of a facility capable of conducting the DOE test procedure for pumps within the scope of the rulemaking. Because of a lack of information on existing testing facilities in the industry, as well as the potential variability in the capabilities of these existing facilities, DOE assumed that no manufacturers would have existing test capabilities and all manufacturers would have to construct new test laboratories in order to comply with the test procedure. DOE also assumed in the IRFA that no third party laboratories were available to conduct testing in accordance with the DOE test procedure. 80 FR 17586, 17631 (April 1, 2015).

DOE recognizes that many pump manufacturers already have pump test facilities and conduct pump testing as part of an existing manufacturing quality control process, to develop pump performance information for new and existing products, and to demonstrate the performance of specific pump units for customers. As such, for the purposes of estimating testing burden associated with this test procedure final rule, DOE has revised the baseline assumptions regarding the existing test lab capabilities of manufacturers and has estimated the incremental burden associated with just those test procedure requirements that would not typically exist in current manufacturer facilities. DOE describes these updated assumptions and analysis in section IV.B.3.

Regarding the capabilities of existing test laboratories, HI commented that it disagrees with DOE's assumption in the NOPR that the use of a non-calibrated test motor and VFD with a torque meter would be the most common and least costly approach for testing bare pumps in accordance with the proposed DOE test procedure. (HI, No. 0008 at p. 24) Additionally, HI noted that it did not find anything in the NOPR preamble that mentions recertification requirements. (HI, No. 0008 at p. 25)

DOE acknowledges comments from HI on the underestimated cost estimates to build a pump testing facility and suggestions of components. DOE disagrees with HI that a VFD control would not be the most common approach for testing pumps in accordance with the DOE test procedure. DOE conducted a literature search for pump configurations and determined that almost all controls available to be paired with pumps are VFD controls. DOE also reiterates that the estimates used in the IRFA were not meant to be the least costly for manufacturers. The cost estimates for constructing a test facility were meant to be the most burdensome on manufacturers to show the most costly approach to building a test facility. DOE acknowledges the comment from HI regarding recertification requirements and clarifies that the estimates for recertification requirements in the April 2015 pumps test procedure NOPR IRFA are for pumps which have been redesigned to capture market preferences or other customer requirements. DOE estimates that 10 percent of basic models per manufacturer will be redesigned and tested each year, and the Department has included the costs of testing newly redesigned pumps in this DOE test procedure final rule regulatory flexibility analysis (see section IV.B.3). To further clarify these costs, DOE has removed the terminology used in the

April 2015 pumps test procedure NOPR IRFA regarding recertification that was unclear. Instead, in this final rule, DOE uses redesigned and tested to refer to pumps that would require new certifications each year, as their energy performance will have changed as a result of the equipment redesign. DOE notes that only those pump models for which the energy consumption characteristics have changed necessitate a new basic model certification and that pump models whose energy consumption characteristics have not changed do not need to be recertified.

HI agreed that, for most pump models, only physical testing of the underlying bare pump model is required, and subsequent rating for that bare pump sold with a motor or motor and continuous control can be based on calculations only. (HI, No. 0008 at p. 24) HI also stated that all pumps listed within the scope as outlined in the term sheet can be evaluated in accordance with the methodology described in the April 2015 pumps test procedure NOPR if the corrected equation presented by DOE at the April 29, 2015 public meeting is used. (HI, No. 0008 at p. 24) HI stated that it could not comment on the number of pump models per manufacturer that would be required to use the test (wire-to-water) method to certify pump performance based on a lack of data, but stated that 100 percent of pumps would need to be tested to certify because of the new testing requirements and sampling provisions. (HI, No. 0008 at p. 25)

DOE appreciates the comment from HI that only physical testing of the underlying bare pump is required and that subsequent configurations can be based on calculations. DOE agrees with HI that 100 percent of pumps would need to be tested to certify compliance with a proposed PEI standard, if adopted in a standards final rule. This is true for PEI_{CL} and PEI_{VL} because these values cannot be calculated without the finalized C-Values from the energy conservation standards rulemaking. In addition, the PER_{CL} and PER_{VL} metrics contain specific assumptions regarding the representative performance of pumps and pump components that are not part of the industry's current test methods. However, as noted in section III.F, DOE recognizes that manufacturers already make some representations regarding the performance of relevant pumps (e.g., pump efficiency, BEP efficiency, and pump total head or volume rate of flow (flow rate) at BEP and full impeller) based on testing using test standards consistent with or similar to HI 40.6–2014, which DOE is incorporating by reference as the basis for the DOE test procedure. As such, DOE notes that, while all PEI_{CL}, $PEI_{VL,}$ PER_{CL}, and PER_{VL} ratings must be newly-generated, some existing test data that were collected consistent with the methods DOE is incorporating by reference into the DOE test procedure may be used, provided manufacturers are confident any such values are equivalent to those that would be generated using the new DOE test procedure.

Quantity of Manufacturers Potentially Affected

To calculate the burden associated with testing pumps on aper manufacturer or per model basis, DOE collected information on the number of manufacturers in the pumps industry, and the numbers of models per manufacturer. DOE then focused this analysis on the small entities as part of the regulatory flexibility analysis. To determine which pump manufacturers were small entities, DOE referenced the Small Business Administration (SBA) size threshold for "Pump and Pumping Equipment Manufacturing"

(North American Industry Classification System code 333911).[75] The SBA sets a threshold of 500 employees or less for an entity to be considered as a small business for this category, as established at 13 CFR 121.201.

In the April 2015 pumps test procedure NOPR, DOE conducted a focused inquiry into small business manufacturers of equipment covered by this rulemaking. DOE identified 68 distinct manufacturers of covered pump products sold in the U.S. DOE then analyzed those 68 to determine which would be considered a small business. After removing entities that are foreign owned or operated, DOE determined that there were 25 small businesses in the analysis. These 25 companies represent 29 percent of pump manufacturers with facilities in the United States. 80 FR 17586, 17629 (April 1, 2015).

In response to DOE's assessment of the number of small manufacturers subject to the pumps test procedure rule, HI commented that the HI organization currently has 106 member companies (pump manufacturers and associate members) and is aware of more entities within the market. HI believes that the identification of 68 distinct pump manufacturers in the U.S. is low. (HI, No. at pp. 23-24)

DOE appreciates the comment from HI that there are more manufacturers in the pump manufacturing industry that are not included in this analysis. DOE notes that although HI might have associate members, if the member does not manufacture a pump, the associate member is not part of the analysis. During its market survey, DOE used

[75] See http://www.sba.gov/sites/default/files/files/Size_Standards_Table.pdf.

available public information to identify potential small manufacturers. DOE's research involved the review of individual company websites and marketing research tools (e.g., Dun and Bradstreet reports, Manta, Hoovers) to create a list of companies that manufacture pumps covered by this rulemaking. DOE also contacted HI to obtain information about pump manufacturing companies that participate in the national association. DOE identified 86 potential businesses of covered pump products sold in the U.S., but reduced that number to 68 by determining which businesses were located in the United States. From these manufacturers, DOE eliminated 29 from the analysis because they had more than 500 employees. DOE removed an additional 16 manufacturers because they either had foreign parent companies or had domestic parent companies with 500 or more employees. After removing entities that are foreign owned or operated, DOE determined that there were 25 small businesses to investigate for this analysis. The regulatory flexibility analysis investigated manufacturers who manufacture pumps within the scope of this rulemaking, are considered a small business according to SBA standards, and are not foreign-owned or operated. Thus, there are fewer manufacturers analyzed in the regulatory flexibility analysis than are present in the industry.

In summary, DOE agrees with HI that 68 distinct manufacturers is low on an industry-wide basis, but that is because the number was reduced by other criteria before being presented in the April 2015 pumps test procedure NOPR. DOE notes that HI is not disagreeing with DOE's assessment of the quantity of small businesses, but rather the potential size of total pump manufacturers in the U.S. Following the April 2015 pumps test procedure NOPR, DOE has not identified any more (or different) manufacturers that meet the criteria (domestic headquarters, not owned by another entity, meets the SBA threshold of 500 employees or fewer) to be considered a small business. Therefore, in this final rule, DOE maintains the quantity of 25 small businesses for purposes of analyzing the potential burden. Within the 25 small businesses, DOE has, however, identified an additional manufacturer that produces pumps that are within the scope of this rulemaking and have included this manufacturer in this DOE pumps test procedure final rule regulatory flexibility analysis (raising the total from 15 to 16).

Manufacturer Sales to Assess Burden

In the April 2015 pumps test procedure NOPR, DOE used average sales to assist in assessing the potential burden. 80 FR 17586, 17629 (April 1, 2015). HI commented that it has no alternative to offer other than using the average sales, but noted that it does not understand what DOE is presenting in Table IV.2 [of the April 2015 pumps test procedure NOPR]. (HI, No. 0008 at p. 25)

DOE agrees with HI that there is no better alternative to using average sales as the financial indicator for assessing the burden on manufacturers. DOE notes that Table IV.2 in the April 2015 pumps test procedure NOPR displays the results of the initial regulatory flexibility analysis. 80 FR 17586, 17633 (April 1, 2015). The columns indicate the range of number of employees in each row; the number of small businesses within each employee size range; the average number of basic models produced by manufacturers in each employee size range; and the average sales of the manufacturers in each employee size range as determined from available data sources. Using the estimated potential testing burden, number of basic models, and the average annual sales, DOE determined the potential burden as a percentage of sales of each group of small businesses (as defined by ranges of numbers of employees). Because DOE maintains that this final rule has no incremental burden associated with it when viewed as a stand-alone rulemaking, DOE is only presenting the estimates of the costs associated with testing equipment consistent with the requirements of this test procedure final rule, as would be required to certify compliance with potential energy conservation standards. As such, this table of impacts on manufacturers as a result of conducting this test procedure is no longer included in this regulatory flexibility analysis.

HI commented that there will be a significant burden on both small and large entities and believes that this estimated value would vary depending on the size of the pump manufacturer. (HI, No. 0008 at pp. 25-26)

DOE agrees that the estimated burden may vary based on the size of the manufacturers if energy conservation standards are promulgated. DOE only considered the aggregate effects on small manufacturers of developing certified ratings for applicable pump models for the purposes of making representations regarding the energy use of such equipment or certifying compliance to DOE under any future energy conservation standards. The estimated burden of conducting the DOE test procedure presented in the April 2015 pumps test procedure NOPR showed that, as the number of employees increased, so did the number of basic models and average sales. As a result, as the number of employees increased, the average estimated burden, as a percentage of average annual sales, decreased. Based on this analysis, it is likely that the burden may vary based on the size of manufacturer.

DOE cannot confirm HI's comment that there will be a significant burden on large manufacturers because the regulatory flexibility analysis aims to assess whether there is a significant economic impact on a substantial number of small entities. DOE did not assess the impact of the rule on large entities. However, DOE notes that the parallel energy conservation standards rulemaking includes a full manufacturer impact analysis (Docket No. EERE-2011_BT-STD-0031).

3. Revised Assessment of Burden Associated with this Test Procedure Final Rule

In the initial regulatory flexibility analysis portion of the April 2015 pumps test procedure NOPR, DOE estimated the most burdensome costs for manufacturers to conduct the DOE test procedure. In the initial regulatory flexibility analysis DOE recognized that, because testing is not currently required or standardized, testing facilities may vary widely from one pump manufacturer to another. For the purposes of estimating testing burden in the initial regulatory flexibility analysis, DOE estimated the burden associated with a situation where a given pump manufacturer did not have existing test facilities at all and would be required to construct such facilities to test equipment in accordance with the test procedure. In light of comments received regarding the burden associated with testing, DOE revised the analysis and gathered additional information to better characterize the expected burden associated with testing basic models in accordance with the DOE test procedure.

DOE is analyzing the effect of the combined burden associated with both the test procedure and energy conservation standards rulemakings in the manufacturer impact analysis performed as part of the energy conservation standards rulemaking (see docket EERE-2011-BT-STD-0031). The costs described in the following subsection are referenced in the manufacturer impact analysis in the pumps energy conservation standards rulemaking to estimate the burden associated with testing. However, DOE reiterates that the estimates provided serve only to provide information about the possible burden manufacturers may incur while testing pumps using this DOE test procedure; they do not represent actual burden incurred by the industry as there is no incremental burden associated with this test procedure final rule until and unless the associated pumps energy conservation standards final rule is published.

The DOE test procedure will require pump manufacturers to conduct the calculation-based method or the testing-based method, depending on the type and configuration of the pump(s) being tested. DOE is adopting the less burdensome calculation-based test method as the required test method for bare pumps, and as optional test methods for pumps other than bare pumps. This includes pumps sold with motors that are covered by DOE's electric motor energy conservation standards or submersible motors and pumps sold with either of these two motor styles that are also sold with continuous controls (see section III.E for a more thorough description of the applicability of the calculation-based approach to different pump configurations). DOE is also requiring that manufacturers use a testing-based method where pumps are sold either with motors that are not covered by DOE's electric motor energy conservation standards (except submersible motors) or with non-continuous controls.

Both the calculation-based method and the testing-based method require physical testing of pumps at some level and, as such, utilize a similar basic testing facility. DOE recognizes that all manufacturers, regardless of HI membership, have access to test facilities to be able to produce pump curves that characterize the performance of their equipment. As such, DOE estimated that all manufacturers would be able to conduct the DOE test procedure in an available test facility.

Sixteen of 25 small manufacturers identified in DOE's survey of manufacturers produce pumps that fall within the scope of this rulemaking and would be required to perform testing; the other 9 produce pump types that are not within the scope of pumps for which this test procedure is applicable. Of the 16 manufacturers that produce pumps within the scope of this rulemaking, 8 are members of HI according to their listing on HI's website.[76]

As member companies of HI, DOE assumes that manufacturers with pumps within the scope of this test procedure would test pumps in accordance with HI's most current industry testing standards. That is, DOE assumes that manufacturers that are HI members already conduct testing in accordance with HI 40.6–2014. In HI 40.6–2014, manufacturers are required to test their pumps in an ISO 9906 Grade 2B test facility,

[76] See http://www.pumps.org/member_companies.aspx

which is the same grade test facility prescribed in HI 14.6-2011. Because the calculation-based method described in this test procedure is equivalent to HI 40.6–2014, as recommended by the Working Group, manufacturers who are members of HI would already be capable of testing pumps in accordance to the testing-based method in this test procedure. There is no incremental cost to calibrate measurement instrumentation for these manufacturers because HI 40.6–2014 prescribes calibration intervals for all instruments in the test facility. The testing-based method in this test procedure requires electrical measurement equipment capable of measuring true RMS current, true RMS voltage, and real power up to at least the 40^{th} harmonic of fundamental supply source frequency with an accuracy level of ±2.0 percent of full scale when measured at the fundamental supply source frequency, as discussed in section III.C.2.e. Electrical equipment accuracy of ±2.0 percent of reading is consistent with the value specified in section 40.6.3.2.3 of HI 40.6-2014. Therefore, the is no incremental cost to conduct testing for HI member companies when testing pumps pursuant to the testing-based method or the calculation-based method.

Manufacturers who are not members of HI need to purchase electrical measurement equipment with ±2.0 percent accuracy to conduct the testing-based method of the DOE test procedure. DOE determined that the average cost of such equipment is approximately $5,218.42 based on a review of available products on the market. Unlike the manufacturers who are HI members, the non-HI manufacturers may not perform regular equipment calibration and, as such, will incur an additional cost to calibrate the instruments in the test facility. DOE assumed that each testing facility would need to calibrate the instrumentation used in the test loop as specified in HI 40.6–2014 appendix D. The flowmeter, torque sensor, and power quality meter all should be calibrated once a year. The pressure transducer should be calibrated every 4 months and a laser tachometer should be calibrated every 3 years. These calibrations, together, cost a manufacturer about $1,241.67 per year.

DOE analyzed the estimated burden for 7 years for the 16 small manufacturers that produce pumps within the scope of the DOE test procedure. DOE used an analysis period of 7 years based on the assumption that the machinery qualifies for a 7-year depreciation schedule under the Modified Accelerated Cost Recovery System (MACRS).[77] The average, and representative, of the likely burden to manufacturers is $6,334 for the capital costs associated with constructing a test facility capable of conducting the DOE test procedure. This burden ranges between $0 and $12,668.

Both methods of the test procedure require test personnel to set up, conduct, and remove each pump in accordance with that procedure. DOE estimated the cost of labor using the median hourly wage of $41.44 for the overall category of an engineer.[78] Including fringe benefits, which are estimated to be nominally 30 percent of total compensation, the total hourly cost to an employer is estimated to be $53.87.[79]

---

[77] Department of the Treasury, Internal Revenue Service. How to Depreciate Property. IRS Pub. 926.
[78] U.S. Department of Labor, Bureau of Labor Statistics. 2012. National Occupational Employment and Wage Estimates. Washington, D.C. Available at http://www.bls.gov/oes/2012/may/oes_nat.htm#17-0000.
[79] U.S. Department of Labor, Bureau of Labor Statistics. 2014. Employer Costs for Employee Compensation - Management, Professional, and Related Employees. Washington, D.C. Available at: http://www.bls.gov/news.release/pdf/ecec.pdf.

Based on conversations with test engineers, DOE estimates it would take between 1 and 2 hours of an engineer's time to complete the test procedure per unit tested, which would result in a cost of $53.87 to $107.74 per unit based on an engineer's labor rate of $53.87 per hour. DOE estimates that setting up and removing the pumps from the test stand would require 2 to 6 hours of the engineer's time depending on the size of the pump and any other fittings that need to be configured to enable testing, resulting in a cost between $107.74 to $323.22 per unit based on the labor rate of $53.87 per hour for an engineer. The total cost of testing a pump, including setup, tests, and takedown ranges between $161.61 and $430.96 per unit. DOE estimates that the time required to conduct the calculation-based method of test would be the same as the time required to conduct the test-based method (wire-to-water test).

DOE also estimates that pump manufacturers would redesign covered pump models or introduce new pump models each year. As such, DOE estimates that a certain portion of the pump models that a given pump manufacturer offers for sale would need to be tested each year. DOE estimates that approximately 10 percent of manufacturers' unique pump models would need to be tested each year.

DOE amortized the capital costs against the recurring burden of testing pumps described in this analysis for each small manufacturer identified to produce pumps covered under the scope of the DOE test procedure. DOE notes that the labor component represents the majority of the overall cost associated with testing, while the much more variable capital costs are only 23 percent of the total test cost. The representative amortized burden for testing each unit of a basic model is $561.16. As discussed in the sampling provisions in section III.G, this test procedure will require manufacturers to test at least two units of each pump basic model to develop a certified rating. This results in an average cost of $1,122.32 to test two units of each basic model.

While analyzing the potential burdens of testing pumps in-house, DOE recognized that the price per basic model was higher for some manufacturers than for others. For manufacturers with higher costs of testing per basic model may elect to send their pumps to a third-party test facility to mitigate these costs. DOE anticipates that third party testing facilities will update their test facilities to be able to provide testing for pump manufacturers in accordance with the DOE test procedure. Based on market research and discussions with third party test lab personnel, DOE estimates that testing pumps in a third party test facility according to the DOE test procedure will cost approximately $2,500 per unit.

4. Calculator Comments

Wilo indicated that one problem is that DOE is not responsible for providing tools to determine compliance, so each manufacturer would be responsible for creating its own potentially erroneous evaluation tool. (Wilo, No. 0044 at p. 3-4) HI requested that DOE share the latest version of the PEI calculator with the pump industry as an easy means of determining whether their products fall within or outside the scope of the efficiency levels specified in the rulemaking. (HI, No. 0002 at p. 1) HI also requested that DOE provide a PEI calculator so that all calculations for PEI are performed exactly the same way by all members of the pump industry, government agencies and interested parties.

(HI, No. 0007 at p. 2) HI commented that the calculator could be used to report data to interested utilities. (HI, No. 0007 at p. 10) HI also commented that the complexity of the rating systems will cause a significant burden on all manufacturers to develop a tool which quickly evaluates product. This is even more important for small and medium-sized companies that may not have the resources to develop such an analytic tool on their own. (HI, No. 0008 at p. 2)

In response to the comments submitted by Wilo and HI, DOE made the PEI calculator available on the pumps test procedure rulemaking website.[80] Under the provisions in this pumps test procedure final rule, the PEI calculations must be performed using measured values – that is, using results from testing actual pumps in accordance with the proposed test method and sampling plan. The PEI calculator provided to the public is not considered an Alternative Efficiency Determination Method (AEDM) by the Department and is not to be used to simulate or estimate the efficiency of a pump. DOE has provided this "calculator" as a convenience at the request of interested parties. DOE notes that manufacturers should consult section III.B of this final rule and the adopted regulatory text at 10 CFR 431.464 and appendix A of subpart Y for the formulas for calculating PEI and should not rely on this spreadsheet. DOE also notes that while this calculator is an excel-based version of the calculations in the test procedure proposal, DOE did not rely on this document to develop the proposal itself.

Based on the estimates presented, DOE believes that the test procedure amendments will not have a significant economic impact on a substantial number of

[80] https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/44#testprocedures

small entities, and the preparation of a final regulatory flexibility analysis is not required. DOE will 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).

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 NOPR proposing energy conservation standards for pumps on April 24, 2015. 80 FR 22938. 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 pumps 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). In the April 2015 pumps test procedure NOPR, DOE estimated that it will 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 actually submit the Compliance and Certification Management System templates. 80 FR 17586, 17633 (April 15, 2015).

In response to DOE's April 2015 pump test procedure NOPR, HI commented that the hours shown are low and will vary by the number of basic models covered. (HI, No. at p. 26)

DOE appreciates the comment submitted by HI regarding the burden estimate to comply with the proposed recordkeeping requirements. DOE recognizes that recordkeeping burden may vary substantially based on company preferences and practices as well as the number of basic models each manufacturer will test. However, DOE maintains that, on average, it will take manufacturers approximately 30 hours to comply with the certification and recordkeeping requirements. In addition, DOE notes that, while this test procedure rulemaking includes recordkeeping requirements that are associated with executing and maintaining the test data for this equipment, the certification requirements would be established in a final rule establishing energy conservation standards for pumps.

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 final rule, DOE amends its test procedure for pumps. 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 rule amends an existing rule without affecting the amount, quality or distribution of energy usage, and, therefore, will not result in any environmental impacts. Thus, this rulemaking is covered by Categorical Exclusion A5 under 10 CFR part 1021, subpart D, which applies to any rulemaking that interprets or amends an existing 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 will follow in the development of such regulations. 65 FR 13735. DOE examined this final rule and determined that it will 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 that are the subject of this final 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, this final 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 regulatory action resulting 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; also available at http://energy.gov/gc/office-general-counsel. DOE examined this final 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 final rule will 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 will 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 (Feb. 22, 2002), and DOE's guidelines were published at 67 FR 62446 (Oct. 7, 2002). DOE has reviewed this final 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 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 significant energy action, the agency must give a detailed statement of any adverse effects on energy supply, distribution, or use if the regulation is implemented, and of reasonable alternatives to the action and their expected benefits on energy supply, distribution, and use.

This regulatory action 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 final rule incorporates by reference the testing methods contained in HI 40.6–2014, "Methods for Rotodynamic Pump Efficiency Testing," except section 40.6.5.3, "Test report;" section A.7, "Testing at temperatures exceeding 30 °C(86 °F);" and appendix B, "Reporting of test results." In addition, the final rule's definitions incorporate by reference the following standards:

1) sections 1.1, "types and nomenclature," and 1.2.9, "rotodynamic pump icons," of the 2014 version of ANSI/HI 1.1-1.2–2014, "American National Standard for Rotodynamic Centrifugal Pumps for Nomenclature and Definitions;"
2) section 2.1, "types and nomenclature," of the 2014 version of ANSI/HI 2.1-2.2, "American National Standard for Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions."
3) FM Class Number 1319, "Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type)," approved January 2015.
4) NFPA 20-2016, "Standard for the Installation of Stationary Pumps for Fire Protection," approved 2016.

5) ANSI/UL 448-2013, "Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service," approved 2013.

While this test procedure is not exclusively based on these industry testing standards, some components of the DOE test procedure adopt definitions, test parameters, measurement techniques, and additional calculations from them without amendment. The Department has evaluated these industry testing standards and is unable to conclude whether they would 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 has consulted with both the Attorney General and the Chairman of the FTC about the impact on competition of using the methods contained in this standard, as well as the effects of the rule in general, if promulgated. Regarding any impact on competition that the adopted test procedure may have, the DOJ reviewed the April 2015 pumps test procedure NOPR, attended the April 2015 NOPR public meeting, and consulted with members of the industry in preparing their comments and conclusions regarding any anticompetitive effects of the pumps test procedure. In response to the proposed test procedure, DOJ commented that it is not able to determine whether or not the proposed test procedure (or associated energy conservation standard) will lessen competition within the industry. However, DOJ noted that it is concerned about the possibility of anticompetitive effects resulting from the burden and expense of compliance. (DOJ, No. 14 at p. 2) In response to DOJ's concern regarding the burden of conducting the test procedure, DOE has revised several of the requirements, which DOE believes will mitigate DOJ's (and manufacturers') concerns. DOE addresses these concerns regarding the burden related to testing pumps in accordance with the test procedure in section IV.B.

M. Congressional Notification

As required by 5 U.S.C. 801, DOE will report to Congress on the promulgation of this rule before its effective date. The report will state that it has been determined that the rule is not a “major rule” as defined by 5 U.S.C. 804(2).

N. Description of Materials Incorporated by Reference

In this final rule, DOE is incorporating by reference specific sections from a method of test published by HI, titled “Methods for Rotodynamic Pump Efficiency Testing.” Specifically, the test procedure codified by this final rule references HI 40.6–2014, except section 40.6.5.3, “Test report;” section A.7, “Testing at temperatures exceeding 30 °C(86 °F);” and appendix B, “Reporting of test results.” HI 40.6–2014 is an industry-accepted standard used to specify methods of testing for determining the head, flow rate, pump power input, driver power input, pump power output, and other relevant parameters necessary to determine the PEI_{CL} or PEI_{VL} of applicable pumps, as described in this final rule.

In addition, the final rule’s definitions incorporate by reference the following sections of the following standards:

1) sections 1.1, “types and nomenclature,” and 1.2.9, “rotodynamic pump icons,” of the 2014 version of ANSI/HI 1.1-1.2–2014, “American National Standard for Rotodynamic Centrifugal Pumps for Nomenclature and Definitions;” and
2) section 2.1, “types and nomenclature,” of the 2014 version of ANSI/HI 2.1-2.2, “American National Standard for Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions.”
3) FM Class Number 1319, “Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type),” approved January 2015.
4) NFPA 20-2016, “Standard for the Installation of Stationary Pumps for Fire Protection,” approved 2015.
5) ANSI/UL 448-2013, “Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service,” ANSI approved 2013.

ANSI/HI 1.1-1.2–2014 and ANSI/HI 2.1-2.2–2014 describe and define specific pump characteristics relevant to the differentiation of pump categories and configurations when applying the DOE test procedure. The FM, NFPA, and ANSI/UL standards describe the relevant technical characteristics and testing requirements to certify certain pumps as fire pumps.

Copies of all HI standards may be purchased from the Hydraulic Institute at 6 Campus Drive, First Floor North, Parsippany, NJ, 07054-4406, or by going to www.pumps.org.

Copies of FM Class Number 1319 can be obtained from: FM Global, 1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062, (781) 762-4300. www.fmglobal.com.

Copies of NFPA 20-2016 can be obtained from: the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169, (617) 770-3000. www.nfpa.org.

Copies of ANSI/UL 448-2013 can be obtained from: UL, 333 Pfingsten Road, Northbrook, IL 60062, (847) 272-8800. http://ul.com.

V. Approval of the Office of the Secretary

The Secretary of Energy has approved publication of this final 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, Imports, Incorporation by reference, Intergovernmental relations, Small businesses.

Issued in Washington, DC, on December 30, 2015.

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

For the reasons stated in the preamble, DOE amends 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, 431.172, 431.192, 431.202, 431.222, 431.242, 431.262, 431.282, 431.292, 431.302, 431.322, 431.442 and 431.462 of this chapter apply for purposes of this part.

*   *   *   *   *

§429.11 [Amended]

3. In paragraphs (a) and (b) remove “429.54” and add “429.62” in its place.

4. Add §429.59 to read as follows:

§429.59 Pumps.

(a) Determination of represented value. Manufacturers must determine the represented value, which includes the certified rating, for each basic model by testing (which includes the calculation-based methods in the test procedure), in conjunction with the following sampling provisions. Manufacturers must update represented values to account for any change in the applicable motor standards in 10 CFR §431.25 and certify amended values as of the next annual certification.

(1) Units to be tested. The requirements of §429.11 are applicable to pumps; and for each basic model, a sample of sufficient size shall be randomly selected and tested to ensure that—

(i) Any value of the constant or variable load pump energy index or other measure of energy consumption must be greater than or equal to the higher of:

(A) 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 maximum of the i^{th} sample;

Or,

(B) The upper 95 percent confidence limit (UCL) of the true mean divided by 1.05, where:

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

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 to subpart B of part 429);

and

(ii) Any measure of energy efficiency of a basic model must be less than or equal to the lower of:

(A) 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 maximum of the i^{th} sample;

Or,

(B) 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).

(b) [Reserved]

§429.70 [Amended]

5. Amend §429.70(a) by removing “429.54” and adding “429.62” in its place.

6. In §429.71, add paragraph (d) to read as follows:

§429.71 Maintenance of records.

* * * * *

(d) When considering if a pump is subject to energy conservation standards under part 431, DOE may need to determine if a pump was designed and constructed to the requirements set forth in Military Specifications: MIL-P-17639F, MIL-P-17881D, MIL-P-17840C, MIL-P-18682D, or MIL-P-18472G. In this case, a manufacturer must provide DOE with copies of the original design and test data that were submitted to appropriate design review agencies, as required by MIL-P-17639F, MIL-P-17881D, MIL-P-17840C, MIL-P-18682D, or MIL-P-18472G. Military specifications and standards are available for review at http://everyspec.com/MIL-SPECS.

§ 429.72 [Amended]

7. Amend §429.72(a) by removing "429.54" and adding in its place "429.62".

§ 429.102 [Amended]

8. Amend §429.102(a)(1) by removing "429.54" and adding in its place "429.62".

9. Section 429.110, is amended by:

a. Redesignating paragraphs (e)(1)(iv) through (vi) as (e)(1)(v) through (vii), respectively; and

b. Adding a new paragraph (e)(1)(iv).

The addition reads as follows:

§429.110 Enforcement testing.

*   *   *   *   *

(e) * * *

(1) * * *

(iv) For pumps, 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.

10. Section 429.134 is amended by adding paragraph (i) as follows:

§ 429.134. Product-specific enforcement provisions.

* * * * *

(i) Pumps.

(1) The volume rate of flow (flow rate) at BEP and nominal speed of rotation of each tested unit of the basic model will be measured pursuant to the test requirements of §431.464, where the value of volume rate of flow (flow rate) at BEP and nominal speed of rotation certified by the manufacturer will be treated as the expected BEP flow rate. The results of the measurement(s) will be compared to the value of volume rate of flow (flow rate) at BEP and nominal speed of rotation certified by the manufacturer. The certified volume rate of flow (flow rate) at BEP and nominal speed of rotation will be considered valid only if the measurement(s) (either the measured volume rate of flow (flow rate) at BEP and nominal speed of rotation for a single unit sample or the average of the measured flow rates for a multiple unit sample) is within five percent of the certified volume rate of flow (flow rate) at BEP and nominal speed of rotation.

(i) If the representative value of volume rate of flow (flow rate) at BEP and nominal speed of rotation is found to be valid, the measured volume rate of flow (flow rate) at BEP and nominal speed of rotation will be used in subsequent calculations of constant load pump energy rating (PER_{CL}) and constant load pump energy index (PEI_{CL}) or variable load pump energy rating (PER_{VL}) and variable load pump energy index (PEI_{VL}) for that basic model.

(ii) If the representative value of volume rate of flow (flow rate) at BEP and nominal speed of rotation is found to be invalid, the mean of all the measured volume rate of flow (flow rate) at BEP and nominal speed of rotation values determined from the tested unit(s) will serve as the new expected BEP flow rate and the unit(s) will be retested until such time as the measured volume rate of flow (flow rate) at BEP and nominal speed of rotation is within 5 percent of the expected BEP flow rate.

(2) DOE will test each pump unit according to the test method specified by the manufacturer in the certification report submitted pursuant to §429.59(b).

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

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

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

12. Add subpart Y to part 431 to read as follows:

SUBPART Y – Pumps

Sec.

431.461 Purpose and scope.
431.462 Definitions.

SUBPART Y – Pumps

§431.461 Purpose and scope.

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

§431.462 Definitions.

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 takes precedence over any descriptions or definitions found in the 2014 version of ANSI/HI 1.1-1.2, "American National Standard for Rotodynamic Centrifugal Pumps for Nomenclature and Definitions" (ANSI/HI 1.1-1.2–2014) (incorporated by reference, see §431.463), or the 2014 version of ANSI/HI 2.1-2.2, "American National Standard for Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions" (ANSI/HI 2.1-2.2–2014) (incorporated by reference, see §431.463). In cases where definitions reference design intent, DOE will consider marketing materials, labels and certifications, and equipment design to determine design intent.

<u>Bare pump</u> means a pump excluding mechanical equipment, driver, and controls.

Basic model means all units of a given class of pump manufactured by one manufacturer, having the same primary energy source, and having essentially identical electrical, physical, and functional (or hydraulic) characteristics that affect energy consumption, energy efficiency, water consumption, or water efficiency; except that:

(1) For RSV and ST pumps, all variations in numbers of stages of the bare pump must be considered a single basic model;

(2) Pump models for which the bare pump differs in impeller diameter, or impeller trim, may be considered a single basic model; and

(3) Pump models for which the bare pump differs in number of stages or impeller diameter and which are sold with motors (or motors and controls) of varying horsepower may only be considered a single basic model if:

(i) for ESCC, ESFM, IL, and RSV pumps, each motor offered in the basic model has a nominal full load motor efficiency rated at the Federal minimum (see the current table for NEMA Design B motors at 10 CFR 431.25) or the same number of bands above the Federal minimum for each respective motor horsepower (see Table 3 of Appendix A to Subpart Y of Part 431); or

(ii) for ST pumps, each motor offered in the basic model has a full load motor efficiency at the default nominal full load submersible motor efficiency shown in Table 2 of appendix A to subpart Y of part 431 or the same number of bands above the default nominal full load submersible motor efficiency for each respective motor horsepower (see Table 3 of Appendix A to Subpart Y of Part 431).

Best efficiency point (BEP) means the pump hydraulic power operating point (consisting of both flow and head conditions) that results in the maximum efficiency.

Bowl diameter means the maximum dimension of an imaginary straight line passing through and in the plane of the circular shape of the intermediate bowl of the bare pump that is perpendicular to the pump shaft and that intersects the outermost circular shape of the intermediate bowl of the bare pump at both of its ends, where the intermediate bowl is as defined in ANSI/HI 2.1-2.2–2014.

Clean water pump means a pump that is designed for use in pumping water with a maximum non-absorbent free solid content of 0.016 pounds per cubic foot, and with a maximum dissolved solid content of 3.1 pounds per cubic foot, provided that the total gas content of the water does not exceed the saturation volume, and disregarding any additives necessary to prevent the water from freezing at a minimum of 14 °F.

Close-coupled pump means a pump in which the motor shaft also serves as the impeller shaft for the bare pump.

Continuous control means a control that adjusts the speed of the pump driver continuously over the driver operating speed range in response to incremental changes in the required pump flow, head, or power output.

Control means any device that can be used to operate the driver. Examples include, but are not limited to, continuous or non-continuous controls, schedule-based controls, on/off switches, and float switches.

Driver means 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.

Dry rotor pump means a pump in which the motor rotor is not immersed in the pumped fluid.

End suction close-coupled (ESCC) pump means a close-coupled, dry rotor, end suction pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and that is not a dedicated-purpose pool pump. Examples include, but are not limited to, pumps within the specified horsepower range that comply with ANSI/HI nomenclature OH7, as described in ANSI/HI 1.1-1.2–2014.

End suction frame mounted/own bearings (ESFM) pump means a mechanically-coupled, dry rotor, end suction pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and that is not a dedicated-purpose pool pump. Examples include, but are not limited to, pumps within the specified horsepower range that comply with ANSI/HI nomenclature OH0 and OH1, as described in ANSI/HI 1.1-1.2–2014.

End suction pump means a single-stage, rotodynamic pump in which the liquid enters the bare pump in a direction parallel to the impeller shaft and on the side opposite the bare pump's driver-end. The liquid is discharged through a volute in a plane perpendicular to the shaft.

Fire pump means a pump that is compliant with NFPA 20-2016 (incorporated by reference, see §431.463), "Standard for the Installation of Stationary Pumps for Fire Protection," and is either:

(1) UL listed under ANSI/UL 448-2013 (incorporated by reference, see §431.463), "Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service," or

(2) FM Global (FM) approved under the January 2015 edition of FM Class Number 1319, "Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type)," (incorporated by reference, see §431.463).

Full impeller diameter means the maximum diameter impeller with which a given pump basic model is distributed in commerce.

Horizontal motor means a motor that requires the motor shaft to be in a horizontal position to function as designed, as specified in the manufacturer literature.

In-line (IL) pump means a pump that is either a twin-head pump or a single-stage, single-axis flow, dry rotor, rotodynamic pump that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter, in which liquid is discharged through a volute in a plane perpendicular to the shaft. Such pumps do not include pumps that are mechanically coupled or close-coupled, have a pump power output that is less than or equal to 5 hp at BEP at full impeller diameter, and are distributed in commerce with a horizontal motor. Examples of in-line pumps include, but are not limited to, pumps within the specified horsepower range that comply with ANSI/HI nomenclature OH3, OH4, or OH5, as described in ANSI/HI 1.1-1.2–2014.

Magnet driven pump means a pump in which the bare pump is isolated from the motor via a containment shell and torque is transmitted from the motor to the bare pump via magnetic force. The motor shaft is not physically coupled to the impeller or impeller shaft.

Mechanical equipment means any component of a pump that transfers energy from the driver to the bare pump.

Mechanically-coupled pump means a pump in which the bare pump has its own impeller shaft and bearings and so does not rely on the motor shaft to serve as the impeller shaft.

Non-continuous control means a control that adjusts the speed of a driver to one of a discrete number of non-continuous preset operating speeds, and does not respond to incremental reductions in the required pump flow, head, or power output.

Prime-assist pump means a pump that:

(1) Is designed to lift liquid that originates below the centerline of the pump inlet;

(2) Requires no manual intervention to prime or re-prime from a dry-start condition; and

(3) Includes a device, such as a vacuum pump or air compressor and venturi eductor, to remove air from the suction line in order to automatically perform the prime or re-prime function at any point during the pump's operating cycle.

Pump means equipment designed to move liquids (which may include entrained gases, free solids, and totally dissolved solids) by physical or mechanical action and includes a bare pump and, if included by the manufacturer at the time of sale, mechanical equipment, driver, and controls.

Radially split, multi-stage, vertical, in-line diffuser casing (RSV) pump means a vertically suspended, multi-stage, single axis flow, dry rotor, rotodynamic pump:

(1) That has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and at the number of stages required for testing and

(2) In which liquid is discharged in a place perpendicular to the impeller shaft; and

(3) For which each stage (or bowl) consists of an impeller and diffuser;

(4) For which no external part of such a pump is designed to be submerged in the pumped liquid; and

(5) Examples include, but are not limited to, pumps complying with ANSI/HI nomenclature VS8, as described in ANSI/HI 2.1-2.2–2014.

Rotodynamic pump means a pump in which energy is continuously imparted to the pumped fluid by means of a rotating impeller, propeller, or rotor.

Self-priming pump means a pump that:

(1) Is designed to lift liquid that originates below the centerline of the pump inlet;

(2) Contains at least one internal recirculation passage; and

(3) Requires a manual filling of the pump casing prior to initial start-up, but is able to re-prime after the initial start-up without the use of external vacuum sources, manual filling, or a foot valve.

Single axis flow pump means a pump in which the liquid inlet of the bare pump is on the same axis as the liquid discharge of the bare pump.

Submersible turbine (ST) pump means a single-stage or multi-stage, dry rotor, rotodynamic pump that is designed to be operated with the motor and stage(s) fully submerged in the pumped liquid; that has a shaft input power greater than or equal to 1 hp and less than or equal to 200 hp at BEP and full impeller diameter and at the number of stages required for testing; and in which each stage of this pump consists of an impeller and diffuser, and liquid enters and exits each stage of the bare pump in a direction parallel to the impeller shaft. Examples include, but are not limited to, pumps within the specified horsepower range that comply with ANSI/HI nomenclature VS0, as described in ANSI/HI 2.1-2.2–2014.

Twin head pump means a dry rotor, single-axis flow, rotodynamic pump that contains two impeller assemblies, which both share a common casing, inlet, and discharge, and each of which

(1) Contains an impeller, impeller shaft (or motor shaft in the case of close-coupled pumps), shaft seal or packing, driver (if present), and mechanical equipment (if present);

(2) Has a shaft input power that is greater than or equal to 1 hp and less than or equal to 200 hp at best efficiency point (BEP) and full impeller diameter;

(3) Has the same primary energy source (if sold with a driver) and the same electrical, physical, and functional characteristics that affect energy consumption or energy efficiency;

(4) Is mounted in its own volute; and

(5) Discharges liquid through its volute and the common discharge in a plane perpendicular to the impeller shaft.

§431.463 Materials incorporated by reference.

(a) General. DOE incorporates by reference the following standards into subpart Y of part 431. The material listed has been approved for incorporation by reference by the Director of the Federal Register in accordance with 5 U.S.C. 552(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: 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. These standards can be obtained from the sources below.

(b) FM. FM Global, 1151 Boston-Providence Turnpike, P.O. Box 9102, Norwood, MA 02062, (781) 762-4300. www.fmglobal.com.

(1) FM Class Number 1319, “Approval Standard for Centrifugal Fire Pumps (Horizontal, End Suction Type),” January 2015, IBR approved for §431.462.

(2) [Reserved]

(c) HI. Hydraulic Institute, 6 Campus Drive, First Floor North, Parsippany, NJ 07054-4406, 973-267-9700. www.Pumps.org.

(1) ANSI/HI 1.1-1.2–2014, (“ANSI/HI 1.1-1.2–2014”), “American National Standard for Rotodynamic Centrifugal Pumps for Nomenclature and Definitions,” approved October 30, 2014, section 1.1, “Types and nomenclature,” and section 1.2.9, “Rotodynamic pump icons,” IBR approved for §431.462.

(2) ANSI/HI 2.1-2.2–2014, (“ANSI/HI 2.1-2.2–2014”), “American National Standard for Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions,” approved April 8, 2014, section 2.1, “Types and nomenclature,” IBR approved for §431.462.

(3) HI 40.6–2014, (“HI 40.6–2014”), “Methods for Rotodynamic Pump Efficiency Testing,” (except section 40.6.5.3, “Test report;” Appendix A, section A.7, “Testing at temperatures exceeding 30 °C (86 °F);” and Appendix B, “Reporting of test results (normative);”) copyright 2014, IBR approved for appendix A to subpart Y of part 431.

(d) NFPA. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, (617) 770-3000. www.nfpa.org.

(1) NFPA 20, (“NFPA 20-2016”), “Standard for the Installation of Stationary Pumps for Fire Protection,” 2016 Edition, approved June 15, 2015, IBR approved for §431.462.

(2) [Reserved]

(e) UL. UL, 333 Pfingsten Road, Northbrook, IL 60062, (847) 272-8800. ul.com.

(1) UL 448, ("ANSI/UL 448-2013"), "Standard for Safety Centrifugal Stationary Pumps for Fire-Protection Service," 10th Edition, June 8, 2007, including revisions through July 12, 2013, IBR approved for §431.462.

(2) [Reserved]

§431.464 Test procedure for measuring and determining energy consumption of pumps.

(a) Scope. This section provides the test procedures for determining the constant and variable load pump energy index for:

(1) The following categories of clean water pumps:

(i) End suction close-coupled (ESCC);

(ii) End suction frame mounted/own bearings (ESFM);

(iii) In-line (IL);

(iv) Radially split, multi-stage, vertical, in-line casing diffuser (RSV); and

(v) Submersible turbine (ST) pumps

(2) With the following characteristics:

(i) Flow rate of 25 gpm or greater at BEP and full impeller diameter;

(ii) Maximum head of 459 feet at BEP and full impeller diameter and the number of stages required for testing (see section 1.2.2 of appendix A of this subpart);

(iii) Design temperature range from 14 to 248 °F;

(iv) Designed to operate with either: (1) a 2- or 4-pole induction motor, or (2) a non-induction motor with a speed of rotation operating range that includes speeds of rotation between 2,880 and 4,320 revolutions per minute and/or 1,440 and 2,160 revolutions per minute, and in either case, the driver and impeller must rotate at the same speed;

(v) For ST pumps, a 6-inch or smaller bowl diameter; and

(vi) For ESCC and ESFM pumps, a specific speed less than or equal to 5000 when calculated using U.S. customary units.

(3) Except for the following pumps:

(i) Fire pumps;

(ii) Self-priming pumps;

(iii) Prime-assist pumps;

(iv) Magnet driven pumps;

(v) Pumps designed to be used in a nuclear facility subject to 10 CFR part 50, "Domestic Licensing of Production and Utilization Facilities;" and

(vi) Pumps meeting the design and construction requirements set forth in Military Specifications: MIL-P-17639F, "Pumps, Centrifugal, Miscellaneous Service, Naval Shipboard Use" (as amended); MIL-P-17881D, "Pumps, Centrifugal, Boiler Feed, (Multi-Stage)" (as amended); MIL-P-17840C, "Pumps, Centrifugal, Close-Coupled, Navy Standard (For Surface Ship Application)" (as amended); MIL-P-18682D, "Pump, Centrifugal, Main Condenser Circulating, Naval Shipboard" (as amended); and MIL-P-18472G, "Pumps, Centrifugal, Condensate, Feed Booster, Waste Heat Boiler, And Distilling Plant" (as amended). Military specifications and standards are available for review at http://everyspec.com/MIL-SPECS.

(b) Testing and Calculations. Determine the applicable constant load pump energy index (PEI_{CL}) or variable load pump energy index (PEI_{VL}) using the test procedure set forth in appendix A of this subpart Y.

APPENDIX A TO SUBPART Y OF PART 431 – UNIFORM TEST METHOD FOR THE MEASUREMENT OF ENERGY CONSUMPTION OF PUMPS.

Note: Starting on **[INSERT DATE 180 DAYS AFTER DATE OF PUBLICATION IN THE FEDERAL REGISTER]**, any representations made with respect to the energy use or efficiency of pumps subject to testing pursuant to 10 CFR 431.464 must be made in accordance with the results of testing pursuant to this appendix.

I. Test Procedure for Pumps.

A. General. To determine the constant load pump energy index (PEI_{CL}) for bare pumps and pumps sold with electric motors or the variable load pump energy index (PEI_{VL}) for pumps sold with electric motors and continuous or non-continuous controls, perform testing in accordance with HI 40.6–2014, except section 40.6.5.3, “Test report;” section A.7, “Testing at temperatures exceeding 30 °C (86 °F);” and appendix B, “Reporting of test results;” (incorporated by reference, see §431.463) with the modifications and additions as noted throughout the provisions below. Where HI 40.6–2014 refers to “pump,” the term refers to the “bare pump,” as defined in §431.462. Also, for the purposes of applying this appendix, the term “volume per unit time,” as defined in section 40.6.2, “Terms and definitions,” of HI 40.6–2014 shall be deemed to be synonymous with the term “flow rate” used throughout that standard and this appendix. In addition, the specifications of section 40.6.4.1 of HI 40.6−2014 do not apply to ST pumps and the performance of ST bare pumps considers the bowl performance only.

A.1 Scope. Section II of this appendix is applicable to all pumps and describes how to calculate the pump energy index (section II.A) based on the pump energy rating for the minimally compliant reference pump (PER_{STD}; section II.B) and the constant load pump energy rating (PER_{CL}) or variable load pump energy rating (PER_{VL}) determined in accordance with one of sections III through VII of this appendix, based on the configuration in which the pump is distributed in commerce and the applicable testing method specified in sections III through VII and as described in Table 1 of this appendix.

Table 1. Applicability of Calculation-Based and Testing-Based Test Procedure Options Based on Pump Configuration

Pump Configuration	**Pump Sub-Configuration**	**Applicable Test Methods**
Bare Pump	Bare Pump OR Pump + Single-Phase Induction Motor OR Pump + Driver Other Than Electric Motor	Section III: Test Procedure for Bare Pumps
Pump + Motor*	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards** OR Pump + Submersible Motor	Section IV: Testing-Based Approach for Pumps Sold with Motors OR Section V: Calculation-Based Approach for Pumps Sold with Motors
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors) **, ***	Section IV: Testing-Based Approach for Pumps Sold with Motors
Pump + Motor + Continuous Controls OR Pump + Motor + Non-Continuous Controls	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards** + Continuous Control OR Pump + Submersible Motor + Continuous Control	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls OR Section VII: Calculation-Based Approach for Pumps Sold with Motors Controls
	Pump + Polyphase Motor Covered by DOE's Electric Motor Energy Conservation Standards** + Non-Continuous Control OR Pump + Submersible Motor + Non-Continuous Control	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls
	Pump + Motor Not Covered by DOE's Electric Motor Energy Conservation Standards (Except Submersible Motors)**, *** + Continuous or Non-Continuous Controls	Section VI: Testing-Based Approach for Pumps Sold with Motors and Controls

* Also applies if unit is sold with controls other than continuous or non-continuous controls (e.g., ON/OFF switches).
** All references to "Motors Covered by DOE's Electric Motor Energy Conservation Standards" refer to those listed at §431.25(g) of this chapter.
*** Includes pumps sold with single-phase induction motors.

Section III of this appendix addresses the test procedure applicable to bare pumps. This test procedure also applies to pumps sold with drivers other than motors and pumps sold with single-phase induction motors.

Section IV of this appendix addresses the testing-based approach for pumps sold with motors, which is applicable to all pumps sold with electric motors, including single-phase induction motors. This test procedure also applies to pumps sold with controls other than continuous or non-continuous controls (e.g., on/off switches).

Section V of this appendix addresses the calculation-based approach for pumps sold with motors, which applies to:

(1) Pumps sold with polyphase electric motors regulated by DOE's energy conservation standards for electric motors at §431.25(g), and

(2) Pumps sold with submersible motors.

Section VI of this appendix addresses the testing-based approach for pumps sold with motors and controls, which is applicable to all pumps sold with electric motors (including single-phase induction motors) and continuous or non-continuous controls.

Section VII of this appendix discusses the calculation-based approach for pumps sold with motors and controls, which applies to:

(1) Pumps sold with polyphase electric motors regulated by DOE's energy conservation standards for electric motors at §431.25(g) and continuous controls and

(2) Pumps sold with submersible motors and continuous controls.

B. Measurement Equipment. For the purposes of measuring pump power input, driver power input to the motor or controls, and pump power output, the equipment specified in HI 40.6–2014 Appendix C (incorporated by reference, see §431.463) necessary to measure head, speed of rotation, flow rate, temperature, torque, and electrical power must be used and must comply with the stated accuracy requirements in HI 40.6–2014 Table 40.6.3.2.3 except as noted in sections III.B, IV.B, V.B, VI.B, and VII.B of this appendix. When more than one instrument is used to measure a given parameter, the combined accuracy, calculated as the root sum of squares of individual instrument accuracies, must meet the specified accuracy requirements.

C. Test Conditions. Conduct testing at full impeller diameter in accordance with the test conditions, stabilization requirements, and specifications of HI 40.6–2014 (incorporated by reference, see §431.463) section 40.6.3, "Pump efficiency testing;" section 40.6.4, "Considerations when determining the efficiency of a pump;" section 40.6.5.4 (including appendix A), "Test arrangements;" and section 40.6.5.5, "Test conditions.". For ST pumps, head measurements must be based on the bowl assembly total head as described in section A.5 of 40.6–2014 and the pump power input or driver power input, as applicable, must be based on the measured input power to the driver or bare pump, respectively; section 40.6.4.1, "vertically suspended pumps," does not apply to ST pumps.

C.1 Nominal Speed of Rotation. Determine the nominal speed of rotation based on the range of speeds of rotation at which the pump is designed to operate, in accordance with sections I.C.1.1, I.C.1.2, I.C.1.3, I.C.1.4, or I.C.1.5 of this appendix, as applicable. When determining the range of speeds at which the pump is designed to operate, DOE will refer to published data, marketing literature, and other publically-available information about the pump model and motor, as applicable.

C.1.1 For pumps sold without motors, select the nominal speed of rotation based on the speed for which the pump is designed. For bare pumps designed for speeds of rotation including 2,880 to 4,320 revolutions per minute (rpm), the nominal speed of rotation shall be 3,600 rpm. For bare pumps designed for speeds of rotation including 1,440 to 2,160 rpm, the nominal speed of rotation shall be 1,800 rpm.

C.1.2 For pumps sold with 4-pole induction motors, the nominal speed of rotation shall be 1,800 rpm.

C.1.3 For pumps sold with 2-pole induction motors, the nominal speed of rotation shall be 3,600 rpm.

C.1.4 For pumps sold with non-induction motors where the operating range of the pump and motor includes speeds of rotation between 2,880 and 4,320 rpm, the nominal speed of rotation shall be 3,600 rpm.

C.1.5 For pumps sold with non-induction motors where the operating range of the pump and motor includes speeds of rotation between 1,440 and 2,160 rpm, the nominal speed of rotation shall be 1,800 rpm.

C.2 Multi-stage Pumps. For RSV and ST pumps, perform testing on the pump with three stages for RSV pumps and nine stages for ST pumps. If the basic model of pump being tested is only available with fewer than the required number of stages, test the pump with the maximum number of stages with which the basic model is distributed in commerce in the United States. If the basic model of pump being tested is only available with greater than the required number of stages, test the pump with the lowest number of stages with which the basic model is distributed in commerce in the United States. If the basic model of pump being tested is available with both fewer and greater than the required number of stages, but not the required number of stages, test the pump with the number of stages closest to the required number of stages. If both the next lower and next higher number of stages are equivalently close to the required number of stages, test the pump with the next higher number of stages.

C.3 Twin Head Pumps. For twin head pumps, perform testing on an equivalent single impeller IL pump, constructed by incorporating one of the driver and impeller assemblies of the twin head pump being rated into an adequate, IL style, single impeller volute and casing. An adequate, IL style, single impeller volute and casing means a volute and casing for which any physical and functional characteristics that affect energy consumption and energy efficiency are the same to their corresponding characteristics for a single impeller in the twin head pump volute and casing.

D. Data Collection and Analysis.

D.1 Damping Devices. Use of damping devices, as described in section 40.6.3.2.2 of HI 40.6−2014 (incorporated by reference, see §431.463), are only permitted to integrate up to the data collection interval used during testing.

D.2 Stabilization. Record data at any tested load point only under stabilized conditions, as defined in HI 40.6–2014 section 40.6.5.5.1 (incorporated by reference, see §431.463), where a minimum of two measurements are used to determine stabilization.

D.3 Calculations and Rounding. Normalize all measured data to the nominal speed of rotation of 3,600 or 1,800 rpm based on the nominal speed of rotation selected for the pump in section I.C.1 of this appendix, in accordance with the procedures specified in section 40.6.6.1.1 of HI 40.6–2014 (incorporated by reference, see §431.463). Except for the "expected BEP flow rate," all terms and quantities refer to values determined in accordance with the procedures set forth in this appendix for the rated pump. Perform all calculations using raw measured values without rounding. Round PER_{CL} and PER_{VL} to three significant digits, and round PEI_{CL}, and PEI_{VL} values, as applicable, to the hundredths place (i.e., 0.01).

D.4 Pumps with BEP at Run Out.

Test pumps for which the expected BEP corresponds to a volume rate of flow that is within 20 percent of the expected maximum flow rate at which the pump is designed to operate continuously or safely (i.e., pumps with BEP at run-out) in accordance with the test procedure specified in this appendix, but with the following exceptions:

(1) Use the following seven flow points for determination of BEP in sections III.D, IV.D, V.D, VI.D, and VII.D of this appendix instead of those specified in those sections: 40, 50, 60, 70, 80, 90, and 100 percent of the expected.

(2) Use flow points of 60, 70, 80, 90, and 100 percent of the expected maximum flow rate of the pump to determine pump power input or driver power input at the specified load points in section III.E.1.1, IV.E.1, V.E.1.1, VI.E.1, and VII.E.1.1 of this appendix instead of those specified in those sections.

(3) To determine of PER_{CL} and PER_{STD}, use load points of 65, 90, and 100 percent of the BEP flow rate determined with the modified flow points specified in this section I.D.4 of this appendix instead of 75, 100, and 110 percent of BEP flow.

II. Calculation of the Pump Energy Index.

A. Determine the PEI of each tested pump based on the configuration in which it is sold, as follows:

A.1. For pumps rated as bare pumps or pumps sold with motors, determine the PEI_{CL} using the following equation:

$$\mathrm{PEI_{CL}} = \frac{\mathrm{PER_{CL}}}{\mathrm{PER_{STD}}}$$

Where:

PEI_{CL} = the pump energy index for a constant load (hp),

PER_{CL} = the pump energy rating for a constant load (hp), determined in accordance with either section III (for bare pumps, pumps sold with single-phase induction motors, and pumps sold with drivers other than electric motors), section IV (for pumps sold with motors and rated using the testing-based approach), or section V (for pumps sold with motors and rated using the calculation-based approach) of this appendix, and

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp), as determined in accordance with section II.B of this appendix.

A.2 For pumps rated as pumps sold with motors and continuous controls or non-continuous controls, determine the PEI_{VL} using the following equation:

$$PEI_{VL} = \frac{PER_{VL}}{PER_{STD}}$$

Where:

PEI_{VL} = the pump energy index for a variable load,

PER_{VL} = the pump energy rating for a variable load (hp) determined in accordance with section VI (for pumps sold with motors and continuous or non-continuous controls rated using the testing-based approach) or section VII of this appendix (for pumps sold with motors and continuous controls rated using the calculation-based approach), and

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp), as determined in accordance with section II.B of this appendix.

B. Determine the pump energy rating for the minimally compliant reference pump (PER_{STD}), according to the following equation:

$$PER_{STD} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{STD} = the PER_{CL} for a pump that is minimally compliant with DOE's energy conservation standards with the same flow and specific speed characteristics as the tested pump (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i for the minimally compliant pump (hp), calculated in accordance with section II.B.1of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1. Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i (hp), calculated in accordance with section II.B.1.1 of this appendix,

L_i = the part load motor losses at load point i (hp), calculated in accordance with section II.B.1.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.1. Determine the pump power input to the minimally compliant pump at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i = \frac{P_{u,i}}{\alpha_i \times \left(\eta_{pump,STD}/100\right)}$$

Where:

P_i = pump power input to the bare pump at load point i (hp),

α_i = 0.947 for 75 percent of the BEP flow rate, 1.000 for 100 percent of the BEP flow rate, and 0.985 for 110 percent of the BEP flow rate;

$P_{u,i}$ = the pump power output at load point i of the tested pump (hp), as determined in accordance with section II.B.1.1.2 of this appendix;

$\eta_{pump,STD}$ = the minimally compliant pump efficiency (%), calculated in accordance with section II.B.1.1.1 of this appendix; and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.1.1 Calculate the minimally compliant pump efficiency based on the following equation:

$$\eta_{pump,STD} = -0.8500 \times \ln(Q_{100\%})^2 - 0.3800 \times \ln(Ns) \times \ln(Q_{100\%}) - 11.480 \times \ln(Ns)^2 + 17.800 \times \ln(Q_{100\%}) + 179.80 \times \ln(Ns) - (C + 555.60)$$

Where:

$\eta_{pump,STD}$ = minimally compliant pump efficiency (%),

$Q_{100\%}$ = the BEP flow rate of the tested pump at full impeller and nominal speed of rotation (gpm),

Ns = specific speed of the tested pump determined in accordance with section II.B.1.1.1.1 of this appendix, and

C = the appropriate C-value for the category and nominal speed of rotation of the tested pump, as listed at §431.466.

B.1.1.1.1 Determine the specific speed of the rated pump using the following equation:

$$N_s = \frac{n_{sp} \times \sqrt{Q_{100\%}}}{(H_{100\%}/S)^{0.75}}$$

Where:

Ns = specific speed,

n_{sp} = the nominal speed of rotation (rpm),

$Q_{100\%}$ = the measured BEP flow rate of the tested pump at full impeller and nominal speed of rotation (gpm),

$H_{100\%}$ = pump total head at 100 percent of the BEP flow rate of the tested pump at full impeller and nominal speed of rotation (ft), and

S = the number of stages with which the pump is being rated.

B.1.1.2 Determine the pump power output at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate using the following equation:

$$P_{u,i} = \frac{Q_i \times H_i \times SG}{3956}$$

Where:

$P_{u,i}$ = the measured pump power output at load point i of the tested pump (hp),

Q_i = the measured flow rate at load point i of the tested pump (gpm),

H_i = pump total head at load point i of the tested pump (ft),

SG = the specific gravity of water at specified test conditions, which is equivalent to 1.00, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$L_i = L_{full} \times y_i$$

Where:

L_i = part load motor losses at load point i (hp),

L_{full} = motor losses at full load (hp), as determined in accordance with section II.B.1.2.1 of this appendix,

y_i = part load loss factor at load point i determined in accordance with section II.B.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

B.1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{\text{MotorHP}}{\left[\eta_{motor,full}/_{100}\right]} - \text{MotorHP}$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the motor horsepower as determined in accordance with section II.B.1.2.1.1 of this appendix (hp), and

$\eta_{motor,full}$ = the default nominal full load motor efficiency as determined in accordance with section II.B.1.2.1.2 of this appendix (%).

B.1.2.1.1 Determine the motor horsepower as follows:

- For bare pumps other than ST pumps, the motor horsepower is determined as the horsepower rating listed in Table 2 of this appendix that is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump.
- For ST bare pumps, the motor horsepower is determined as the horsepower rating listed in Table 2 of this appendix that, is either equivalent to, or the next highest horsepower greater than, the pump

power input to the bare pump at 120 percent of the BEP flow rate of the tested pump divided by a service factor of 1.15.

- For pumps sold with motors, pumps sold with motors and continuous controls, or pumps sold with motors and non-continuous controls, the motor horsepower is the rated horsepower of the motor with which the pump is being tested.

B.1.2.1.2 Determine the default nominal full load motor efficiency as described in section II.B.1.2.1.2.1 of this appendix for pumps other than ST pumps or II.B.1.2.1.2.2 of this appendix for ST pumps.

B.1.2.1.2.1. For pumps other than ST pumps, the default nominal full load motor efficiency is the minimum of the nominal full load motor efficiency standards (open or enclosed) from the table containing the current energy conservation standards for NEMA Design B motors at §431.25, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section II.B.1.2.1.1 of this appendix.

B.1.2.1.2.2. For ST pumps, the default nominal full load motor efficiency is the default nominal full load submersible motor efficiency listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section II.B.1.2.1.1 of this appendix.

B.1.2.2 Determine the part load loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{MotorHP}\right)^3 + 1.2399 \times \left(\frac{P_i}{MotorHP}\right)^2 - 0.4301 \times \left(\frac{P_i}{MotorHP}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = pump power input to the bare pump at load point i (hp),

MotorHP = the motor horsepower (hp), as determined in accordance with section II.B.1.2.1.1 of this appendix,

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$, then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section II.B.1.2.2 to calculate the part load loss factor at each load point i.

III. Test Procedure for Bare Pumps.

A. Scope. This section III applies only to:

(1) Bare pumps,

(2) Pumps sold with drivers other than electric motors, and

(3) Pumps sold with single-phase induction motors.

B. Measurement Equipment. The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section III, and in addition, when testing pumps using a calibrated motor:

(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, and

(2) Any instruments used to measure a particular parameter specified in paragraph (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 root sum of squares of individual instrument accuracies.

C. Test Conditions. The requirements regarding test conditions presented in section I.C of this appendix apply to this section III. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(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

(2) Maintain total harmonic distortion below 12 percent throughout the test.

D. Testing BEP for the Pump. Determine the best efficiency point (BEP) of the pump as follows:

D.1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump and conduct the test at a minimum of the following seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6–2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see §431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6–2014 (incorporated by reference, see §431.463), where the pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6–2014, disregarding the calculations provided in section 40.6.6.2.

E. Calculating the Constant Load Pump Energy Rating. Determine the PER_{CL} of each tested pump using the following equation:

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i (hp), as determined in accordance with section III.E.1 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1 Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i (hp), as determined in section III.E.1.1 of this appendix,

L_i = the part load motor losses at load point i (hp), as determined in accordance with section III.E.1.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1.1 Determine the pump power input at 75, 100, 110, and 120 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the pump power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load points of 75, 100, 110, and 120 percent of the BEP flow rate.

E.1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$L_i = L_{full} \times y_i$$

Where:

L_i = motor losses at load point i (hp),

L_{full} = motor losses at full load (hp), as determined in accordance with section III.E.1.2.1 of this appendix,

y_i = loss factor at load point i as determined in accordance with section III.E.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{\text{MotorHP}}{\left[\eta_{motor,full}/100\right]} - \text{MotorHP}$$

Where:

L_{full} = motor losses at full load (hp);

MotorHP = the motor horsepower (hp), as determined in accordance with section II.E.1.2.1.1 of this appendix, and

$\eta_{motor,full}$ = the default nominal full load motor efficiency (%), as determined in accordance with section III.E.1.2.1.2 of this appendix.

E.1.2.1.1 Determine the motor horsepower as follows:

- For bare pumps other than ST pumps, determine the motor horsepower by selecting the horsepower rating listed in Table 2 of this appendix that is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump.

- For ST bare pumps, determine the motor horsepower by selecting the horsepower rating listed in Table 2 of this appendix that, is either equivalent to, or the next highest horsepower greater than, the pump power input to the bare pump at 120 percent of the BEP flow rate of the tested pump divided by a service factor of 1.15.
- For pumps sold with motors, pumps sold with motors and continuous controls, or pumps sold with motors and non-continuous controls, the motor horsepower is the rated horsepower of the motor with which the pump is being tested.

E.1.2.1.2 Determine the default nominal full load motor efficiency as described in section III.E.1.2.1.2.1 of this appendix for pumps other than ST pumps or III.E.1.2.1.2.2. of this appendix for ST pumps.

E.1.2.1.2.1. For pumps other than ST pumps, the default nominal full load motor efficiency is the minimum of the nominal full load motor efficiency standards (open or enclosed) from the table containing the current energy conservation standards for NEMA Design B motors at §431.25, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section III.E.1.2.1.1 of this appendix.

E.1.2.1.2.2. For ST pumps, the default nominal full load motor efficiency is the default nominal full load submersible motor efficiency listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower determined in section III.E.1.2.1.1 of this appendix;

E.1.2.2 Determine the loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{\text{MotorHP}}\right)^3 + 1.2399 \times \left(\frac{P_i}{\text{MotorHP}}\right)^2 - 0.4301 \times \left(\frac{P_i}{\text{MotorHP}}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = pump power input to the bare pump at load point i (hp), as determined in accordance with section III.E.1.1 of this appendix,

MotorHP = as determined in accordance with section III.E.1.2.1 of this appendix (hp),

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{\text{MotorHP}} \le 1.000$; if $\frac{P_i}{\text{MotorHP}} > 1.000$, then set $\frac{P_i}{\text{MotorHP}} = 1.000$ in the equation in this section III.E.1.2.2 of this appendix to calculate the part load loss factor at each load point i.

IV. Testing-Based Approach for Pumps Sold with Motors.

A. Scope. This section IV applies only to pumps sold with electric motors, including single-phase induction motors.

B. Measurement Equipment. The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section IV, and in addition, the electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. Test Conditions. The requirements regarding test conditions presented in section I.C of this appendix apply to this section IV. The following conditions also apply to the mains power supplied to the motor:

(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.

D. Testing BEP for the Pump. Determine the BEP of the pump as follows:

D.1 Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6–2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see §431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum overall efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6–2014 (incorporated by reference, see §431.463), where the overall efficiency is the ratio of the pump power output divided by the driver power input, as specified in Table 40.6.2.1 of HI 40.6–2014, disregarding the calculations provided in section 40.6.6.2.

E. Calculating the Constant Load Pump Energy Rating. Determine the PER_{CL} of each tested pump using the following equation:

$$\mathrm{PER_{CL}} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

P_i^{in} = measured driver power input to the motor at load point i (hp) for the tested pump as determined in accordance with section IV.E.1 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1 Determine the driver power input at 75, 100, and 110 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the driver power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the driver power input at the nominal speed of rotation for the load points of 75, 100, and 110 percent of the BEP flow rate.

V. Calculation-Based Approach for Pumps Sold with Motors

A. Scope. This section V can only be used in lieu of the test method in section IV of this appendix to calculate the index for pumps sold with motors listed in section V.A.1 or V.A.2 of this appendix.

A.1 Pumps sold with motors subject to DOE's energy conservation standards for polyphase electric motors at §431.25(g), and

A.2. Pumps sold with submersible motors.

A.3. Pumps sold with motors not listed in sections V.A.1 or V.A.2 of this appendix cannot use this section V and must apply the test method in section IV of this appendix.

B. Measurement Equipment. The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section V, and in addition, when testing pumps using a calibrated motor electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40^{th} harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. Test Conditions. The requirements regarding test conditions presented in section I.C of this appendix apply to this section V. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(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.

D. Testing BEP for the Bare Pump. Determine the best efficiency point (BEP) of the pump as follows:

D.1 Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6–2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see §431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6–2014 (incorporated by reference, see §431.463), where pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6–2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. <u>Calculating the Constant Load Pump Energy Rating.</u> Determine the PER_{CL} of each tested pump using the following equation:

$$PER_{CL} = \sum_{i=75\%,100\%,110\%} \omega_i P_i^{in,m}$$

Where:

PER_{CL} = the pump energy rating for a constant load (hp),

ω_i = 0.3333,

$P_i^{in,m}$ = calculated driver power input to the motor at load point i for the tested pump as determined in accordance with section V.E.1 of this appendix (hp), and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1 Determine the driver power input at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$P_i^{in,m} = P_i + L_i$$

Where:

$P_i^{in,m}$ = driver power input to the motor at load point i (hp),

P_i = pump power input to the bare pump at load point i, as determined in section V.E.1.1 of this appendix (hp),

L_i = the part load motor losses at load point i as determined in accordance with section V.E.1.2 of this appendix (hp), and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1.1 Determine the pump power input at 75, 100, 110, and 120 percent of the BEP flow rate by employing a least squares regression to determine a linear relationship between the pump power input at the nominal speed of rotation of the pump and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load points of 75, 100, 110, and 120 percent of the BEP flow rate.

E.1.2 Determine the motor part load losses at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$L_i = L_{full} \times y_i$$

Where:

L_i = motor losses at load point i (hp),

L_{full} = motor losses at full load as determined in accordance with section V.E.1.2.1 of this appendix (hp),

y_i = part load loss factor at load point i as determined in accordance with section V.E.1.2.2 of this appendix, and

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate.

E.1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[\eta_{motor,full}/_{100}\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp), and

$\eta_{motor,full}$ = the represented nominal full load motor efficiency (i.e., nameplate/DOE-certified value) or default nominal full load submersible motor efficiency as determined in accordance with section V.E.1.2.1.1 of this appendix (%).

E.1.2.1.1 For pumps sold with motors other than submersible motors, determine the represented nominal full load motor efficiency as described in section V.E.1.2.1.1.1 of this appendix. For pumps sold with submersible motors determine the default nominal full load submersible motor efficiency as described in section V.E.1.2.1.1.2 of this appendix.

E.1.2.1.1.1. For pumps sold with motors other than submersible motors, the represented nominal full load motor efficiency is that of the motor with which the given pump model is being tested, as determined in accordance with the DOE test procedure for electric motors at § 431.16 and applicable representation procedures in parts 429 and 430.

E.1.2.1.1.2. For pumps sold with submersible motors, the default nominal full load submersible motor efficiency is that listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower of the pump being tested.

E.1.2.2 Determine the loss factor at each load point corresponding to 75, 100, or 110 percent of the BEP flow rate as follows:

$$y_i = -0.4508 \times \left(\frac{P_i}{MotorHP}\right)^3 + 1.2399 \times \left(\frac{P_i}{MotorHP}\right)^2 - 0.4301 \times \left(\frac{P_i}{MotorHP}\right) + 0.6410$$

Where:

y_i = the part load loss factor at load point i,

P_i = the pump power input to the bare pump at load point i as determined in accordance with section V.E.1.1 of this appendix (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp),

i = load point corresponding to 75, 100, or 110 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$ then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section V.E.1.2.2 of this appendix to calculate the part load loss factor at each load point i.

VI. Testing-Based Approach for Pumps Sold with Motors and Controls.

A. Scope. This section VI applies only to pumps sold with electric motors, including single-phase induction motors, and continuous or non-continuous controls. For the purposes of this section VI, all references to “driver input power” in this section VI or HI 40.6–2014 (incorporated by reference, see §431.463) refer to the input power to the continuous or non-continuous controls.

B. Measurement Equipment. The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section VI, and in addition electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40th harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. Test Conditions. The requirements regarding test conditions presented in section I.C of this appendix apply to this section VI. The following conditions also apply to the mains power supplied to the continuous or non-continuous control:

(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.

D. Testing BEP for the Pump. Determine the BEP of the pump as follows:

D.1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6–2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see §431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum overall efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6–2014 (incorporated by reference, see §431.463), where overall efficiency is the ratio of the pump power output divided by the driver power input, as specified in Table 40.6.2.1 of HI 40.6–2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. Calculating the Variable Load Pump Energy Rating. Determine the PER_{VL} of each tested pump using the following equation:

$$PER_{VL} = \sum_{i=25\%,50\%75\%,100\%} \omega_i P_i^{in,c}$$

Where:

PER_{VL} = the pump energy rating for a variable load (hp);

ω_i = 0.25;

$P_i^{in,c}$ = the normalized driver power input to continuous or non-continuous controls at load point i for the tested pump as determined in accordance with section VI.E.1 of this appendix; and i = load point corresponding 25, 50, 75, or 100 percent of the BEP flow rate.

E.1. Determine the driver power input at 100 percent of the measured BEP flow rate of the tested pump by employing a least squares regression to determine a linear relationship between the measured driver power input at the nominal speed of rotation of the pump and the measured flow rate, using the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the driver power input at the nominal speed of rotation for the load point of 100 percent of the measured BEP flow rate of the tested pump.

E.2 Determine the driver power input at 25, 50, and 75 percent of the BEP flow rate by measuring the driver power input at the load points defined by:

(1) Those flow rates, and

(2) The associated head points calculated according to the following reference system curve equation:

$$H_i = \left(0.80 \times \frac{{Q_i}^2}{{Q_{100\%}}^2} + 0.20\right) \times H_{100\%}$$

Where:

H_i = pump total head at load point i (ft),

$H_{100\%}$ = pump total head at 100 percent of the BEP flow rate and nominal speed of rotation (ft),

Q_i = flow rate at load point i (gpm),

$Q_{100\%}$ = flow rate at 100 percent of the BEP flow rate and nominal speed of rotation (gpm), and

i = load point corresponding to 25, 50, or 75 percent of the measured BEP flow rate of the tested pump.

E.2.1. For pumps sold with motors and continuous controls, the specific head and flow points must be achieved within 10 percent of the calculated values and the measured driver power input must be corrected to the exact intended head and flow conditions using the following equation:

$$P_i^{in,c} = \left(\frac{H_{sp,i}}{H_{M,j}}\right)\left(\frac{Q_{sp,i}}{Q_{M,j}}\right)P_{M,j}^{in,c}$$

Where:

$P_i^{in,c}$ = the corrected driver power input to the continuous or non-continuous controls at load point i (hp),

$H_{sp,i}$ = the specified total system head at load point i based on the reference system curve (ft),

$H_{M,j}$ = the measured total system head at load point j (ft),

$Q_{sp,i}$ = the specified total system flow rate at load point i based on the reference system curve (gpm),

$Q_{M,j}$ = the measured total system flow rate at load point j (gpm),

$P_{M,j}^{in,c}$ = the measured normalized driver power input to the continuous or non-continuous controls at load point j (hp),

i = specified load point at 25, 50, 75, or 100 percent of BEP flow, and

j = measured load point corresponding to specified load point i.

E.2.2. For pumps sold with motors and non-continuous controls, the head associated with each of the specified flow points shall be no lower than 10 percent below that defined by the reference system curve equation in section VI.E.2 of this appendix. Only the measured flow points must be achieved within 10 percent of the calculated values. Correct for flow and head as described in section VI.E.2.1, except do not correct measured head values that are higher than the reference system curve at the same flow rate; only correct flow rate and head values lower than the reference system curve at the same flow rate. For head values higher than the system curve, use the measured head points directly to calculate PEI_{VL}.

VII. Calculation-Based Approach for Pumps Sold with Motors and Controls.

A. Scope. This section VII can only be used in lieu of the test method in section VI of this appendix to calculate the index for pumps listed in section VII.A.1 or VII.A.2 of this appendix.

A.1. Pumps sold with motors regulated by DOE's energy conservation standards for polyphase NEMA Design B electric motors at §431.25(g) and continuous controls, and

A.2. Pumps sold with submersible motors and continuous controls.

A.3. Pumps sold with motors not listed in VII.A.1 or VII.A.2 of this appendix and pumps sold without continuous controls, including pumps sold with non-continuous controls, cannot use this section and must apply the test method in section VI of this appendix.

B. Measurement Equipment. The requirements regarding measurement equipment presented in section I.B of this appendix apply to this section VII, and in addition, when testing pumps using a calibrated motor electrical measurement equipment must:

(1) Be capable of measuring true RMS current, true RMS voltage, and real power up to the 40^{th} harmonic of fundamental supply source frequency, and

(2) For all instruments used to measure a given parameter, have a combined accuracy of ±2.0 percent of the measured value at the fundamental supply source frequency, where combined accuracy is the root sum of squares of individual instrument accuracies.

C. Test Conditions. The requirements regarding test conditions presented in section I.C of this appendix apply to this section VII. When testing pumps using a calibrated motor the following conditions also apply to the mains power supplied to the motor:

(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.

D. Testing BEP for the Bare Pump. Determine the BEP of the pump as follows:

D.1. Adjust the flow by throttling the pump without changing the speed of rotation of the pump to a minimum of seven flow points: 40, 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate of the pump at the nominal speed of rotation, as specified in HI 40.6–2014, except section 40.6.5.3, section A.7, and appendix B (incorporated by reference, see §431.463).

D.2. Determine the BEP flow rate as the flow rate at the operating point of maximum pump efficiency on the pump efficiency curve, as determined in accordance with section 40.6.6.3 of HI 40.6–2014 (incorporated by reference, see §431.463), where pump efficiency is the ratio of the pump power output divided by the pump power input, as specified in Table 40.6.2.1 of HI 40.6–2014 and the calculations provided in section 40.6.6.2 are to be disregarded.

E. Calculating the Variable Load Pump Energy Rating. Determine the PER_{VL} of each tested pump using the following equation:

$$PER_{VL} = \sum_{i=25\%,50\%,75\%,100\%} \omega_i P_i^{in,c}$$

Where:

PER_{VL} = the pump energy rating for a variable load (hp);

ω_i = 0.25;

$P_i^{in,c}$ = the calculated driver power input to the continuous or non-continuous controls at load point i for the tested pump as determined in accordance with section VII.E.1 of this appendix; and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E.1 Determine the driver power input at each load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate as follows:

$$P_i^{in,c} = P_i + L_i$$

Where:

$P_i^{in,c}$ = driver power input at to the continuous or non-continuous controls at load point i (hp),

P_i = pump power input to the bare pump at load point i as determined in accordance with section VII.E.1.1 of this appendix (hp),

L_i = the part load motor and control losses at load point i as determined in accordance with section VII.E.1.2 of this appendix (hp), and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E.1.1 Determine the pump power input at 100 percent of the measured BEP flow rate of the tested pump by employing a least squares regression to determine a linear relationship between the measured pump power input at the nominal speed of rotation and the measured flow rate at the following load points: 60, 75, 90, 100, 110, and 120 percent of the expected BEP flow rate. Use the linear relationship to determine the pump power input at the nominal speed of rotation for the load point of 100 percent of the BEP flow rate.

E.1.1.1 Determine the pump power input at 25, 50, and 75 percent of the BEP flow rate based on the measured pump power input at 100 percent of the BEP flow rate and using with the following equation:

$$P_i = \left(0.80 \times \frac{{Q_i}^3}{{Q_{100\%}}^3} + 0.20 \times \frac{Q_i}{Q_{100\%}}\right) \times P_{100\%}$$

Where:

P_i = pump power input at load point i (hp);

$P_{100\%}$ = pump power input at 100 percent of the BEP flow rate and nominal speed of rotation (hp);

Q_i = flow rate at load point i (gpm);

$Q_{100\%}$ = flow rate at 100 percent of the BEP flow rate and nominal speed of rotation (gpm); and

i = load point corresponding to 25, 50, or 75 percent of the measured BEP flow rate of the tested pump.

E.1.2 Calculate the motor and control part load losses at each load point corresponding to 25, 50, 75, and 100 percent of the BEP flow rate as follows:

$$L_i = L_{full} \times z_i$$

Where:

L_i = motor and control losses at load point i (hp),

L_{full} = motor losses at full load as determined in accordance with section VII.E.1.2.1 of this appendix (hp),

z_i = part load loss factor at load point i as determined in accordance with section VII.E.1.2.2 of this appendix, and

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate.

E.1.2.1 Determine the full load motor losses using the appropriate motor efficiency value and horsepower as shown in the following equation:

$$L_{full} = \frac{MotorHP}{\left[{\eta_{motor,full}}/{100}\right]} - MotorHP$$

Where:

L_{full} = motor losses at full load (hp),

MotorHP = the horsepower of the motor with which the pump model is being tested (hp), and

$\eta_{motor,full}$ = the represented nominal full load motor efficiency (i.e., nameplate/DOE-certified value) or default nominal full load submersible motor efficiency as determined in accordance with section VII.E.1.2.1.1 of this appendix (%).

E.1.2.1.1 For pumps sold with motors other than submersible motors, determine the represented nominal full load motor efficiency as described in section VII.E.1.2.1.1.1 of this appendix. For pumps sold with submersible motors, determine the default nominal full load submersible motor efficiency as described in section VII.E.1.2.1.1.2 of this appendix.

E.1.2.1.1.1 For pumps sold with motors other than submersible motors, the represented nominal full load motor efficiency is that of the motor with which the given pump model is being tested, as determined in accordance with the DOE test procedure for electric motors at §431.16 and applicable representation procedures in parts 429 and 430.

E.1.2.1.1.2 For pumps sold with submersible motors, the default nominal full load submersible motor efficiency is that listed in Table 2 of this appendix, with the number of poles relevant to the speed at which the pump is being tested (see section I.C.1 of this appendix) and the motor horsepower of the pump being tested.

E.1.2.2 For load points corresponding to 25, 50, 75, and 100 percent of the BEP flow rate, determine the part load loss factor at each load point as follows:

$$z_i = a \times \left(\frac{P_i}{MotorHP}\right)^2 + b \times \left(\frac{P_i}{MotorHP}\right) + c$$

Where:

z_i = the motor and control part load loss factor at load point i,

a,b,c = coefficients listed in Table 4 of this appendix based on the horsepower of the motor with which the pump is being tested,

P_i = the pump power input to the bare pump at load point i, as determined in accordance with section VII.E.1.1 of this appendix (hp),

MotorHP = the horsepower of the motor with which the pump is being tested (hp),

i = load point corresponding to 25, 50, 75, or 100 percent of the BEP flow rate, and

$\frac{P_i}{MotorHP} \leq 1.000$; if $\frac{P_i}{MotorHP} > 1.000$ then set $\frac{P_i}{MotorHP} = 1.000$ in the equation in this section VII.E.1.2.2 of this appendix to calculate the part load loss factor at load point i.

Table 2. Default Nominal Full Load Submersible Motor Efficiency by Motor Horsepower and Pole

Motor Horsepower <u>hp</u>	Default Nominal Full Load Submersible Motor Efficiency	
	2 poles	4 poles
1	55	68
1.5	66	70
2	68	70
3	70	75.5
5	74	75.5
7.5	68	74
10	70	74
15	72	75.5
20	72	77
25	74	78.5
30	77	80
40	78.5	81.5
50	80	82.5
60	81.5	84
75	81.5	85.5
100	81.5	84
125	84	84
150	84	85.5
200	85.5	86.5
250	86.5	86.5

Table 3. Nominal Full Load Motor Efficiency Values

Nominal Full Load Motor Efficiency*
50.5
52.5
55.0
57.5
59.5
62.0
64.0
66.0
68.0
70.0
72.0
74.0
75.5
77.0
78.5
80.0
81.5
82.5
84.0
85.5
86.5
87.5
88.5
89.5
90.2
91.0
91.7
92.4
93.0
93.6
94.1
94.5
95.0
95.4
95.8
96.2
96.5
96.8
97.1
97.4
97.6
97.8
98.0
98.2
98.4
98.5
98.6
98.7
98.8
98.9
99.0

*Note: Each consecutive incremental value of nominal efficiency represents one band.

Table 4. Motor and Control Part Load Loss Factor Equation Coefficients for Section VII.E.1.2.2 of this Appendix A

Motor Horsepower hp	Coefficients for Motor and Control Part Load Loss Factor (z_i)		
	a	**b**	**c**
≤5	-0.4658	1.4965	0.5303
>5 and ≤20	-1.3198	2.9551	0.1052
>20 and ≤50	-1.5122	3.0777	0.1847
>50	-0.8914	2.8846	0.2625