DEPARTMENT OF ENERGY

10 CFR Part 431

[EERE–2017–BT–TP–0055]

RIN 1904–AE19

Energy Conservation Program: Test Procedure for Distribution Transformers

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

ACTION: Final rule.

SUMMARY: The U.S. Department of Energy (''DOE'') is amending the test procedure for distribution transformers to revise and add definitions of certain terms, update provisions based on the latest versions of relevant industry testing standards, and to specify the basis for voluntary representations at additional per-unit loads and additional reference temperatures. The updates in this final rule will not significantly change the test procedure.

DATES: The effective date of this rule is October 14, 2021. The final rule changes will be mandatory for product testing starting March 14, 2022.

ADDRESSES: The docket, which includes **Federal Register** notices, comments, and other supporting documents/materials, is available for review at *www.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 *www.regulations.gov/docket/EERE-2017-BT-TP-0055.* The docket web page contains instructions on how to access all documents, including public comments, in the docket.

For further information on how to review the docket contact the Appliance and Equipment Standards Program staff at (202) 287–1445 or by email: *ApplianceStandardsQuestions@ee.doe.gov.*

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SUPPLEMENTARY INFORMATION:

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I. Authority and Background

DOE is authorized to establish and amend energy conservation standards and test procedures for certain industrial equipment, including distribution transformers. The current DOE test procedure for distribution transformers appear at title 10 of the Code of Federal Regulations (''CFR'') 431.193 and appendix A to subpart K of 10 CFR part 431 (''appendix A'') respectively. The current energy conservation standards for distribution transformers appear at 10 CFR 431.196. The following sections discuss DOE's authority to establish test procedures for distribution transformers and relevant background information regarding DOE's consideration of test procedures for this equipment.

A. Authority

The Energy Policy and Conservation Act, as amended (''EPCA''),[1] authorizes DOE to regulate the energy efficiency of a number of consumer products and certain industrial equipment. (42 U.S.C. 6291–6317, as codified) Title III, Part B[2] of EPCA established the Energy Conservation Program for Consumer Products Other Than Automobiles (42 U.S.C. 6291–6309, as codified), which sets forth a variety of provisions designed to improve energy efficiency of specified consumer products. Title III, Part C[3] of EPCA, added by the National Energy Conservation Policy Act, Public Law 95–619, Title IV, section 441(a), established the Energy Conservation Program for Certain Industrial Equipment (42 U.S.C. 6311–6317, as codified), which sets forth a variety of provisions designed to improve energy efficiency of certain industrial equipment. This equipment includes distribution transformers, the subject of this final rule. (42 U.S.C. 6317(a))

The energy conservation program under EPCA consists essentially of four parts: (1) Testing, (2) labeling, (3) Federal energy conservation standards, and (4) certification and enforcement procedures. Relevant provisions of EPCA for distribution transformers specifically include definitions (42 U.S.C. 6291; 42 U.S.C. 6311), test procedures (42 U.S.C. 6293; 42 U.S.C. 6317), labeling provisions (42 U.S.C. 6294; 42 U.S.C. 6315), energy conservation standards (42 U.S.C. 6295; 42 U.S.C. 6317), and the authority to require information and reports from manufacturers (42 U.S.C. 6296; 42 U.S.C. 6316).

The Federal testing requirements consist of test procedures that manufacturers of covered products and covered equipment must use as the basis for: (1) Certifying to DOE that their products or equipment comply with the applicable energy conservation standards adopted pursuant to EPCA (42 U.S.C. 6295(s); 42 U.S.C. 6316(a)), and (2) making representations about the efficiency of those covered products or

[1] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Public Law 116–260 (Dec. 27, 2020).

[2] For editorial reasons, upon codification in the U.S. Code, Part B was redesignated Part A.

[3] For editorial reasons, upon codification in the U.S. Code, Part C was redesignated Part A–1.

covered equipment (42 U.S.C. 6293(c); 42 U.S.C. 6314(d)). Similarly, DOE must use these test procedures to determine whether the products or equipment comply with relevant standards promulgated under EPCA. (42 U.S.C. 6295(s); 42 U.S.C. 6316(a))

Federal energy efficiency requirements for covered products and covered equipment established under EPCA generally supersede State laws and regulations concerning energy conservation testing, labeling, and standards. (42 U.S.C. 6297; 42 U.S.C. 6316(a) and (b)) DOE may, however, grant waivers of Federal preemption for particular State laws or regulations, in accordance with the procedures and other provisions of EPCA. (42 U.S.C. 6297(d); 42 U.S.C. 6316(b)(2)(D))

EPCA set forth the criteria and procedures DOE must follow when prescribing or amending test procedures for covered products [4] and covered equipment, respectively. EPCA requires that any test procedures prescribed or amended under these sections be reasonably designed to produce test results which 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 not be unduly burdensome to conduct. (42 U.S.C. 6293(b)(3); *see also* 42 U.S.C. 6314(a)(2))

EPCA also requires that, at least once every 7 years, DOE evaluate test procedures for each type of covered product and covered equipment, including distribution transformers, to determine whether amended test procedures would more accurately or fully comply with the requirements for the test procedures to not be unduly burdensome to conduct and be reasonably designed to produce test results that reflect energy efficiency, energy use, and estimated operating costs during a representative average use cycle. (42 U.S.C. 6293(b)(1)(A); *see also* 42 U.S.C. 6314(a)(1))

If the Secretary determines, on her own behalf or in response to a petition by any interested person, that a test procedure should be prescribed or amended, the Secretary shall promptly publish in the **Federal Register** proposed test procedures and afford interested persons an opportunity to present oral and written data, views, and arguments with respect to such procedures. The comment period on a proposed rule to amend a test procedure shall be at least 60 days and may not exceed 270 days. In prescribing or amending a test procedure, the Secretary shall take into account such information as the Secretary determines relevant to such procedure, including technological developments relating to energy use or energy efficiency of the type (or class) of covered products or covered equipment involved. (42 U.S.C. 6293(b)(2)) If DOE determines that test procedure revisions are not appropriate, DOE must publish its determination not to amend the test procedures. DOE is publishing this final rule in satisfaction of the 7-year review requirement specified in EPCA. (42 U.S.C. 6293(b)(1)(A); *see also* 42 U.S.C. 6314(b)(1))

DOE is issuing this final rule to amend the test procedure for distribution transformers in accordance with its statutory obligations.

B. Background

With respect to distribution transformers, EPCA states that the test procedures for distribution transformers shall be based on the ''Standard Test Method for Measuring the Energy Consumption of Distribution Transformers'' prescribed by the National Electrical Manufacturers Association (NEMA TP 2–1998). (42 U.S.C. 6293(b)(10)(A)) Further, DOE may review and revise the DOE test procedure. (42 U.S.C. 6293(b)(10)(B))

Consistent with the requirements in EPCA, DOE published a final rule on April 27, 2006, that established the test procedure for distribution transformers based on the test methods in NEMA TP 2–1998 and the test methods contained in the Institute of Electrical and Electronics Engineers (''IEEE'') Standards C57.12.90–1999 and C57.12.91–2001. 71 FR 24972, 24974. *See* 71 FR 24972 (April 27, 2006) (''April 2006 Final Rule'').[5]

In a final rule published on April 18, 2013, amending the energy conservation energy conservation standards (''ECS'') for distribution transformers (''April 2013 ECS Final Rule''), DOE determined that the test procedure did not require amendment at that time, concluding that the test procedure as established in the April 2006 Final Rule was reasonably designed to produce test results that reflect energy efficiency and energy use, as required by 42 U.S.C. 6314(a)(2). 78 FR 23336, 23347–23348. The current test procedures for distribution transformers may be found in 10 CFR 431.193 and 10 CFR part 431, subpart K, appendix A.

On September 22, 2017, DOE published a request for information (''RFI'') to collect data and information to inform its consideration of whether to amend DOE's test procedure for distribution transformers (''September 2017 RFI''). 82 FR 44347. After consideration of comments received in response to the September 2017 RFI, DOE published a notice of proposed rulemaking (''NOPR'') on May 10, 2019 (''May 2019 NOPR''), presenting DOE's proposals to amend the distribution transformer test procedure. 84 FR 20704.

DOE received comments in response to the May 2019 NOPR from the interested parties listed in Table I.1.

TABLE I.1—WRITTEN COMMENTS RECEIVED IN RESPONSE TO MAY 2019 NOPR

Organization(s) *	Reference in this document	Organization type
Appliance Standards Awareness Project, American Council for an Energy-Efficient Economy, Natural Resources Defense Council.	Efficiency Advocates	Efficiency Organizations.
Cargill	Cargill	Insulating Liquid Manufacturer.
Copper Development Association	CDA	Trade Association.
Howard Industries Inc	Howard	Manufacturer.
HVOLT Inc	HVOLT	Industry Consultant.
National Electrical Manufacturers Association	NEMA	Trade Association.
Pacific Gas & Electric Company	PG&E	Electrical Utility.

* This list includes only those commenters that provided comments relevant to the May 2019 NOPR.

[4] DOE generally refers to distribution transformers as covered equipment. However, to the extent that DOE is discussing provisions of Part B of EPCA that are applicable to distribution transformers, ''covered product'' is used.

[5] DOE published a technical correction to the April 2006 Final Rule to correct typographical errors. 71 FR 60662 (Oct. 16, 2006).

A parenthetical reference at the end of a comment quotation or paraphrase provides the location of the item in the public record.[6]

II. Synopsis of the Final Rule

In this final rule, DOE amends 10 CFR 431.192, 431.193, 431.196, and appendix A as follows:

(1) Explicitly specify that the test procedure is applicable only to distribution transformers that are subject to energy conservation standards,

(2) Include new definitions for ''per-unit load,'' ''terminal'' and ''auxiliary device,'' and updated definitions for ''low-voltage dry-type distribution transformer'' and ''reference temperature,''

(3) Reflect certain revisions from the latest version of the IEEE testing standards on which the DOE test procedure is based,

(4) Incorporate other clarifying revisions based on review of the DOE test procedure,

(5) Specify use of existing test procedure provisions for voluntary (optional) representations at additional per-unit loads (''PULs'') and reference temperatures, and

(6) Centralize the PUL and reference temperature specifications for certification to energy conservation standards and for voluntary representations.

The adopted amendments are summarized in Table II.1 compared to the test procedure provision prior to the amendment, as well as the reason for the adopted change. Table II.2 compares the changes adopted in this final rule to the proposal of the May 2019 NOPR.

TABLE II.1—SUMMARY OF CHANGES IN THE AMENDED TEST PROCEDURE

DOE test procedure prior to amendment	Amended test procedure (adopted by this final rule)	Attribution
Current test procedure does not specify scope	States explicitly that the scope of the test procedure is limited to the scope of equipment subject to the energy conservation standards.	Clarification added by DOE.
PUL is referred to as ''percent load,'' ''percent of nameplate-rated load,'' ''percent of the rated load,'' or ''per unit load level''.	Consolidates all terms to only ''per-unit load''	Improves consistency and readability of test procedure.
Does not define ''Per-unit load,'' ''Terminal'' and ''Auxiliary device,'' which are used in the current test procedure (TP).	Adds new definitions for ''Per-unit load,'' ''Terminal,'' and ''Auxiliary device''.	Reflects industry testing standard definition (terminal) and clarification added by DOE (PUL and auxiliary device).
Includes definition of ''Low-Voltage Dry-Type Distribution Transformer''.	Updates definition of ''Low-Voltage Dry-Type Distribution Transformer''.	Aligns with industry definition.
Test procedure provisions are based on four IEEE testing standards, which contain general requirements and methods for performing tests: C57.12.00–*2000*. C57.12.01–*1998*. C57.12.90–*1999*. C57.12.91–*2001*.	Updates provisions based on the latest version of the four IEEE testing standards: C57.12.00–*2015*. C57.12.01–*2020*. C57.12.90–*2015*. C57.12.91–*2020*.	Reflects industry testing standard updates.
Requires reporting performance at the rated frequency; however, the rated frequency is not explicitly defined.	States explicitly that all testing under the DOE test procedure is to occur only at 60 Hz.	Update to reflect industry testing standards.
Requires determining winding resistance but does not specify whether the polarity of the core magnetization should be kept constant as measurements are made.	Specifies that the polarity of the core magnetization be kept constant during all resistance readings.	Update to reflect industry testing standards.
Requires the measurement of load and no-load loss, without explicitly specifying the connection locations for measurements.	Specifies explicitly that load and no-load loss measurements are required to be taken only at the transformer terminals.	Update to reflect industry testing standards.
Testing with a sinusoidal waveform explicitly specified only for transformers designed for harmonic currents.	Specifies that all transformers must be tested using a sinusoidal waveform (not just those designed for harmonic current).	Update to reflect industry practice.
Energy conservation standards require that efficiency be determined at a single PUL of 50 percent for both liquid-immersed and medium-voltage dry type (MVDT) distribution transformers, and at 35 percent for low-voltage dry-type (LVDT) distribution transformers.	Permits *voluntary* representations of efficiency, load loss and no-load loss at additional PULs and/or reference temperature, using the DOE test procedure. (Does not require certification to DOE of any voluntary representations.)	Response to industry comment.
Specifies PUL and reference temperature specifications for certification to energy conservation standards in multiple locations throughout appendix A.	Centralizes the PUL and reference temperature specifications, both for the certification to energy conservation standards and for use with a voluntary representation.	Improves readability of test procedure.

[6] The parenthetical reference provides a reference for information located in the docket of DOE's rulemaking to develop test procedures for distribution transformers. (Docket No. EERE–2017–BT–STD–0055, which is maintained at *www.regulations.gov*). The references are arranged as follows: (commenter name, comment docket ID number, page of that document).

TABLE II.2—SUMMARY OF CHANGES—FINAL RULE RELATIVE TO MAY 2019 NOPR

DOE test procedure prior to amendment	NOPR proposal	Final rule
Current test procedure does not specify scope	States explicitly that the scope of the test procedure is limited to the scope of equipment subject to the energy conservation standards.	Adopts modification as proposed.
PUL is referred to as ''percent load,'' ''percent of nameplate-rated load,'' ''percent of the rated load,'' or ''per unit load level''.	Consolidates all terms to only ''per-unit load.''	Adopts modification as proposed.
Does not define ''Per-unit load,'' ''Terminal'' and ''Auxiliary device,'' which are used in the current TP.	Adds new definitions for ''Per-unit load,'' ''Terminal,'' and ''Auxiliary device.''.	Adopts modification as proposed.
Aligns definition of ''Low-Voltage Dry-Type Distribution Transformer'' with industry definition.	Proposes updated definition of ''Low-Voltage Dry-Type Distribution Transformer.''.	Slight change from NOPR to align with industry definition.
Test procedure provisions are based on four IEEE testing standards, which contain general requirements and methods for performing tests: C57.12.00–*2000*. C57.12.01–*1998*. C57.12.90–*1999*. C57.12.91–*2001*.	Updates provisions based on the latest version of the four IEEE testing standards: C57.12.00–*2015*. C57.12.01–*2015*. C57.12.90–*2015*. C57.12.91–*2011*.	Adopts modifications as proposed. Note that after NOPR publication, IEEE updated C57.12.91–2011 and C57.12.01–2015 to C57.12.91–2020 and C57.12.01–2020. The relevant provisions of C57.12.91–2020 and C57.12.01–2020 and the other two testing standards are unchanged.
Automatic Recording of Data Not Required	Requires automatic recording of data, as required in IEEE C57.12.90–2015 and IEEE C57.12.91–2011, using a digital data acquisition system. (Appendix A, section 4.4.2(b)).	NOPR proposal not adopted in this final rule.
Requires reporting performance at the rated frequency; however, the rated frequency is not explicitly defined.	States explicitly that all testing under the DOE test procedure is to occur only at 60 Hz for resistance measurement and no-load loss test.	Adopted no-load loss test as proposed. NOPR proposal not adopted for resistance measurements.
Requires determining winding resistance but does not specify whether the polarity of the core magnetization should be kept constant as measurements are made.	Specifies that the polarity of the core magnetization be kept constant during all resistance readings.	Adopts modification as proposed.
Requires the measurement of load and no-load loss, without explicitly specifying the connection locations for measurements.	Specifies explicitly that load and no-load loss measurements are required to be taken only at the transformer terminals.	Adopts modification as proposed.
Testing with a sinusoidal waveform explicitly specified only for transformers designed for harmonic currents.	Specifies that all transformers must be tested using a sinusoidal waveform (not just those designed for harmonic current).	Adopts modification as proposed.
Energy conservation standards require that efficiency be determined at a single PUL of 50 percent for both liquid-immersed and MVDT distribution transformers, and at 35 percent for LVDT distribution transformers.	Permits *voluntary* representations of efficiency, load loss and no-load loss at additional PULs and/or reference temperature, using the DOE test procedure. (Does not require certification to DOE of any voluntary representations.)	Adopts modification as proposed.
Specifies PUL and reference temperature specifications for certification to energy conservation standards in multiple locations throughout appendix A.	Centralizes the PUL and reference temperature specifications, both for the certification to energy conservation standards and for use with a voluntary representation.	No change from NOPR.

DOE has determined that the amendments described in section III and adopted in this document will not alter the measured efficiency of distribution transformers or require retesting or recertification solely as a result of DOE's adoption of the amendments to the test procedure. Additionally, DOE has determined that the amendments will not increase the cost of testing. Discussion of DOE's actions are addressed in detail in section III of this document.

The effective date for the amended test procedure adopted in this final rule is 30 days after publication of this document in the **Federal Register**. Representations of energy use or energy efficiency must be based on testing in accordance with the amended test procedure beginning 180 days after the publication of this final rule.

III. Discussion

A. Scope of Applicability

The applicability of the test procedure is provided in 10 CFR 431.193, which states that ''the test procedures for measuring the energy efficiency of distribution transformers for purposes of EPCA are specified in appendix A to this subpart.'' DOE has established energy conservation standards for low-voltage dry-type (''LVDT'') distribution transformers, liquid-immersed distribution transformers, and medium-voltage dry type (''MVDT'') distribution transformers at 10 CFR 431.196. In the May 2019 NOPR, DOE proposed to state explicitly that the scope of the test procedure is limited to the scope of the distribution transformers that are subject to energy conservation standards. 84 FR 20704, 20706. DOE did not receive any comments regarding this proposal. DOE is modifying text in 10 CFR 431.193 regarding the scope of the test procedure as proposed.

B. Updates to Industry Testing Standards

The current DOE test procedure for distribution transformers is based on provisions from the following industry testing standards (*See* 71 FR 24972, 24982 (April 27, 2006)):

- NEMA TP 2–1998, ''Standard Test Method for Measuring the Energy Consumption of Distribution Transformers'' (NEMA TP 2–1998)
- IEEE C57.12.90–1999, ''IEEE Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and IEEE Guide for Short Circuit Testing of Distribution and Power Transformers''
- IEEE C57.12.91–2001, ''IEEE Standard Test Code for Dry-Type Distribution and Power Transformers''
- IEEE C57.12.00–2000, ''IEEE Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers''
- IEEE C57.12.01–1998, ''IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including those with Solid Cast and/or Resin Encapsulated Windings''

In addition, the DOE test procedure is also based on provisions in NEMA TP 2–2005,[7] which in turn reference the aforementioned IEEE testing standards.[8] DOE determined that basing the procedure on multiple industry testing standards, as opposed to adopting an industry test procedure (or procedures) without modification, was necessary to provide the detail and accuracy required for the Federal test procedure, with the additional benefit of providing manufacturers the Federal test procedure in a single reference. 71 FR 24972, 24982 (April 27, 2006).

DOE previously sought comment on the benefits and burdens of adopting industry testing standards without modification. 82 FR 44347, 44351 (Sep. 22, 2017). NEMA commented generally that there is benefit but that DOE should limit the reference to the measurement of losses and retain DOE's existing calculation for efficiency. (NEMA, Docket No. EERE–2017–BT–TP–0055–0014 p. 9) DOE stated in the May 2019 NOPR that the current test procedure is already based on industry testing standards and that if DOE were to adopt an industry testing standard without modification, the resulting changes could require manufacturers to retest and recertify, because such an incorporation by reference would require updating a majority of the current test procedure. 84 FR 20704, 20710. For these reasons, DOE did not propose to incorporate industry testing standard into its test procedure for distribution transformers. *Id.*

NEMA further commented that while the existing test procedure is adequate, for high volume units the test procedures found in IEEE C57.12.90–2015 and IEEE C.57.12.91–2011 are less burdensome and recommended that DOE allow them as equivalent alternatives for the purposes of testing and certification. (NEMA, No. 30 at p. 5) As discussed, DOE's test procedure is partially based on the IEEE testing standards, and there are similarities between the DOE test procedure and the IEEE testing standards. There are also minor differences between the DOE test procedure and the IEEE testing standards, such as DOE's requirement to test multiple-voltage-capable distribution transformers in the highest losses configuration (appendix A, sections 4.5.1(b) and 5.0), as discussed in section III.E. Testing according to the IEEE test procedures without modification could result in distribution transformers being tested at different conditions depending on the method used. Therefore, DOE is not permitting use of IEEE testing standards as equivalent alternatives. DOE may consider referencing sections of the IEEE test procedures as equivalent in the future if there is sufficient data and information that doing so would result in equivalent measured efficiency values with the DOE test procedure.

1. Recission of NEMA TP 2

As discussed, EPCA requires that DOE base the test procedure on NEMA TP 2–1998. (42 U.S.C. 6293(b)(10)(A)) Also as discussed, the DOE test procedure is based on (but does not incorporate by reference directly) NEMA TP 2–1998, NEMA TP 2–2005, as well as four IEEE standards that are referenced in NEMA TP 2–2005, *i.e.,* IEEE.C57.12.00, IEEE C57.12.01, IEEE C57.12.90 and IEEE C57.12.91. *See* 71 FR 24972, 24982 (April 27, 2006). As discussed in the following section, updates have been made to the IEEE testing standards.

Since publication of the April 2006 Final Rule, NEMA TP 2–2005 has been rescinded and superseded in industry by the IEEE standards. DOE has evaluated the provisions in the Federal test procedure that are based on NEMA TP 2 and, as discussed in the May 2019 NOPR, has determined that these provisions remain appropriate for testing distribution transformers. DOE did not receive any comments on these provisions in the May 2019 NOPR and therefore maintained them in this final rule.

2. Updates to IEEE Standards

a. Background

As discussed in section III.B, the DOE test procedure mirrors four widely used IEEE testing standards. Since the April 2006 Final Rule, all of the four IEEE standards have been updated.

In the May 2019 NOPR, DOE proposed updating certain Federal test procedure provisions to reflect the following updated versions of the relevant IEEE testing standards: IEEE C57.12.90–2015, IEEE C57.12.91–2011, IEEE C57.12.00–2015, and IEEE C57.12.01–2015. Since publication of the May 2019 NOPR, IEEE issued a further update to standard IEEE C57.12.91 (IEEE C57.12.91–2020) and IEEE C57.12.01–2015 (IEEE C57.12.01–2020). Table III.1 provides a list of old and new versions of each of these IEEE testing standards.

[7] Standard Test Method for Measuring the Energy Consumption of Distribution Transformers, available at: *nema.org/Standards/Pages/Standard-Test-Method-for-Measuring-the-Energy-Consumption-of-Distribution-Transformers.aspx.*

[8] Prior to the April 2006 Final Rule, NEMA provided the Department with its revised test procedure document (*i.e.,* update to NEMA TP 2–1998), TP 2–2005. The Department treated this submission as a comment on DOE's rulemaking to establish a distribution transformer test procedure. 71 FR 24972, 24973. As such, the DOE test procedure incorporated a number of the changes that this revision made to the rule language and addressed the differences between the DOE test procedure and NEMA TP 2–2005. *Id.*

TABLE III.1—IEEE INDUSTRY TESTING STANDARDS VERSIONS AND SUMMARY

IEEE standard	Version on which DOE test procedure prior to amendment is based (year)	Most recent IEEE revision version (year)	Content
C57.12.00	2000	2015	General electrical and mechanical requirements for liquid-immersed distribution transformers.
C57.12.01	1998	2020	General electrical and mechanical requirements for dry-type distribution transformers.
C57.12.90	1999	2015	Methods for performing tests specified in C57.12.00 and others for liquid-immersed distribution transformers.
C57.12.91	2001	2020	Methods for performing tests specified in C57.12.01 and others for dry-type distribution transformers.

b. General Updates

For the May 2019 NOPR, DOE reviewed the then most current editions of the relevant IEEE testing standards to determine whether any of the updates from the previously considered versions warranted proposed amendments to the DOE test procedure. The four IEEE testing standards are not relevant to the DOE test procedure in their entirety, as they include specifications and test methods beyond those required to measure efficiency, such as test methods for polarity, phase-relation, dielectric, and audible sound-level. DOE performed the review as follows:

(1) DOE identified the sections of the IEEE testing standards that form the basis of the DOE test procedure,

(2) DOE compared those sections between the old and the then current versions of the IEEE testing standards, and

(3) DOE initially determined which of the changes were editorial versus which represented potential substantive improvements to the test method.

In IEEE C57.12.90–2015 and IEEE C57.12.91–2011, sections 5, 8, and 9 provide the resistance measurements, the no-load loss test, and the load loss test, respectively, which provide the basis for the DOE test procedure. In general, DOE did not identify major changes in sections 5, 8, and 9 between 1999 and 2015 editions of IEEE C57.12.90–2015, or between the 2001 and 2011 editions of IEEE C57.12.91–2011. Since the May 2019 NOPR, DOE has reviewed the updated IEEE C57.12.91–2020 test procedure and concluded that there were no substantive differences between the relevant provisions in the 2011 and 2020 versions.

The IEEE C57.12.00 and IEEE C57.12.01 testing standards include general electrical and mechanical requirements for the test methods for liquid-immersed and dry-type distribution transformers, in IEEE C57.12.90 and IEEE C57.12.91, respectively. In IEEE C57.12.00 and IEEE C57.12.01, section 9 and section 5, respectively, provide accuracy requirements for conducting the resistance measurements, the no-load loss test, and the load loss test. The primary change DOE identified in the accuracy requirements between the 2000 and 1998 standards and the 2015 standards was a slight relaxation of the temperature system accuracy requirement, from ±1 °C in the older versions to ±1.5 °C for liquid-immersed distribution transformers and ±2 °C for medium-voltage dry-type distribution transformers and low-voltage dry-type distribution transformers. Since the May 2019 NOPR, DOE has reviewed the updated IEEE C57.12.91–2020 test procedure and concluded that there were no substantive differences between the relevant provisions in the 2015 and 2020 versions.

In the May 2019 NOPR, DOE proposed a series of updates based on the then most recent updates to the relevant IEEE testing standards. 84 FR 20704, 20711. DOE stated the proposed updates reflect current industry practice, and as such, would not change current measured values. *Id.* DOE further stated that providing additional specificity consistent with the updates would improve the repeatability of the test procedure. *Id.* DOE requested comment on the proposed changes to reflect the updates to the relevant IEEE testing standards. *Id.*

DOE received comments from Howard, NEMA, CDA, and HVOLT agreeing that the proposed updates are already industry practice and would not change any values or increase testing costs for manufacturers. (Howard, No. 32 at p.1; NEMA, No. 20 at p. 3; CDA, No. 29 at p. 2; HVOLT, No. 27 at p. 91)

Based on its review of the updates to the relevant IEEE testing standards and following consideration of the comments, DOE is adopting the proposed updates and clarifications, with two exceptions, discussed below.

c. Automatic Recording of Data

In the May 2019 NOPR, DOE proposed to require automatic recording of data using a digital data acquisition system at appendix A, section 4.4.2(b), in an attempt to align with industry standards. 84 FR 20704, 20711. NEMA commented that the proposed requirement to automatically record data using a digital data acquisition system is listed in IEEE C57.12.90–2015 and C57.12.91–2020 for making resistance measurements by the voltmeter-ammeter method, and not for the no-load loss measurements as was proposed in the May 2019 NOPR. (NEMA, No. 30 at p. 3) NEMA commented that requiring automatic recording of data using a digital data acquisition system for the no-load losses could require some labs to upgrade test equipment, as not all power analyzers have this capability. *Id.*

DOE acknowledges that IEEE C57.12.90–2015 and C57.12.91–2020 both cite using digital data acquisition systems for making resistance measurements by the voltmeter-ammeter method and not for no-load losses, as was proposed. In an effort to remain aligned with the industry testing standard IEEE C57.12.90–2015 and C57.12.91–2020 no-load loss test, DOE has not adopted the proposal to require automatic recording of data using a digital data acquisition system. DOE is maintaining the current specification in section 4.4.2(b) of appendix A that requires recording data ‘‘as close to simultaneously as possible.’’

d. Test Frequency

In the May 2019 TP NOPR, DOE proposed to require testing under the DOE test procedure to occur only at 60 Hz in appendix A, sections 3.1(c) and 4.1, in order to align with the industry testing standard and provide clarity on the frequency of the test current. 84 FR 20704, 20711.

NEMA commented that there was an error in the proposed language of section 3.1(c) of Appendix A, stating that the proposed regulatory text should read ''Measure resistance with the transformer energized by a DC supply'' rather than with a 60 Hz supply as was proposed in the May 2019 NOPR. (NEMA, No. 30 at p. 5) DOE concurs with NEMA that the 60 Hz supply frequency is not applicable to the resistance measurement section of the test procedure, only to the loss measurement sections. The proposed addition of section 3.1(c) of appendix A, was an error. Resistance measurements are already stated as being a ''direct current resistance'' measurement in appendix A, section 3.1(b). Therefore, DOE is not adopting section 3.1(c) of appendix A as was proposed in the May 2019 NOPR.

The proposed language clarifying the ''Test Frequency'' provision in appendix A, section 4.1, is aligned with the industry standard to test at the ''rated frequency,'' which by the definition of distribution transformer at 10 CFR 431.192 is 60Hz. Therefore, this proposed addition remains appropriate. DOE did not receive any comment in opposition to its proposal to clarify that appendix A, section 4.1, is to be conducted with a 60 Hz frequency current. Therefore, DOE is adopting the change as proposed to section 4.1.

e. Summary of Updates Adopted in This Final Rule

Table III.2 summarizes proposed updates to the relevant IEEE testing standards that are adopted in this final rule. As summarized previously, DOE received comments from industry trade organizations and individual manufacturers indicating that the proposed updates are already industry practice and would not change any values or increase testing costs for manufacturers. (Howard, No. 32 at p. 1; NEMA, No. 30 at p. 3; CDA, No. 29 at p. 2; HVOLT, No. 27 at p. 91) As such, DOE has determined that the following amendments reflect current industry practice and provide additional specificity that will improve the repeatability of the test procedure.

TABLE III.2—IEEE-BASED UPDATES ADOPTED IN THIS FINAL RULE

Topic	Updates based on IEEE standards
Consolidating the Terms ''Oil,'' ''Transformer Liquid,'' and ''Insulating Liquid''.	Replace the term ''oil'' and ''transformer liquid'' with ''insulating liquid'' in Appendix A to reflect that the term is inclusive of all insulating liquids, including those identified in IEEE C57.12.90–2015.
Stability Requirement for Resistance Measurement	Specify, consistent with IEEE C57.12.90–2015, that resistance measurements are considered stable if the top insulating liquid temperature does not vary more than 2 °C in a one-hour period. (Appendix A, section 3.2.1.2(b))
Temperature Test System Accuracy	Relax the temperature test system accuracy requirements to be within ±1.5 °C for liquid-immersed distribution transformers, and ±2.0 °C for MVDT and LVDT distribution transformers, as specified in IEEE C57.12.00–2015 and IEEE C57.12.01–2020, respectively. (Appendix A, section 2.0)
Limits for Voltmeter-Ammeter Method	Permit use of the voltmeter-ammeter method when the rated current of the winding is less than or equal to 1 A. Neither IEEE C57.12.90–2015 nor IEEE C57.12.91–2020 restrict usage of this method to certain current ranges. (Appendix A, section 3.3.2(a))
Number of Readings Required for Resistance Measurement	Include the requirement that a minimum of four readings for current and voltage must be used for each resistance measurement, as specified in IEEE C57.12.90–2015. (Appendix A, section 3.3.2(b))
Connection Locations for Resistance Measurements	Add resistance measurement specifications for single-phase windings, wye windings and delta windings, as provided in section 5.4.1 and 5.4.2 of IEEE C57.12.90–2015, and sections 5.6.1 through 5.6.3 of IEEE C57.12.91–2020. (Appendix A, section 3.4.1(g)–(i))
Test Frequency	Require that all testing under the DOE test procedure is to occur only at 60 Hz. (Appendix A, section 4.1)
Polarity of Core Magnetization	Require that the polarity of the core magnetization be kept constant during all resistance readings. (Appendix A, section 3.4.1(f))

C. Definitions

Definitions pertaining to distribution transformers are provided at 10 CFR 431.192. The following sections discuss new and amended definitions established in this final rule.

1. Rectifier Transformers and Drive Transformers

DOE defines rectifier transformer as a transformer that operates at the fundamental frequency of an alternating-current system and that is designed to have one or more output windings connected to a rectifier.[9] 10 CFR 431.192.

DOE defines drive (isolation) transformer as a transformer that (1) isolates an electric motor from the line; (2) accommodates the added loads of drive-created harmonics; and (3) is designed to withstand the mechanical stresses resulting from an alternating current adjustable frequency motor drive or a direct current motor drive. 10 CFR 431.192. The parenthetical inclusion of the term ''isolation'' indicates that the defined term includes only isolation transformers and not other transformers that may be described as ''drive transformers'' in the industry but which do not satisfy all three criteria specified in the definition of drive (isolation) transformer.

Both rectifier transformers and drive transformers are among the exclusions to the term ''distribution transformer'' at 10 CFR 431.192 and 42 U.S.C. 6293(35)(B)(ii). Because both rectifier transformers and drive transformers are not classified as distribution transformers, they are not subject to the energy conservation standards at 10 CFR 431.196.

[9] A rectifier is an electrical device for converting alternating current to direct current.

Although rectifier transformers and drive transformers are defined differently, they typically share features. As discussed in the May 2019 NOPR, both are isolation transformers (*i.e.,* not autotransformers); both are typically exposed to (and must tolerate) significant harmonic content created from the drive or power supply; and both are likely to include design features enabling them to bear mechanical stress resulting from rapid current changes that may arise from operation of motors and other industrial equipment. 84 FR 207054, 20708.

In response to the September 2017 RFI, Babanna Suresh (''Suresh'') commented that it could be argued that most distribution-type transformers meet the present definition of the terms ''rectifier transformer'' or ''drive transformer'' and suggested that those terms be removed from the list of exclusions to the term ''distribution transformer.'' (Suresh, Docket No. EERE–2017–BT–TP–0055, No. 9 at p. 1) Suresh further suggested that the definition of ''rectifier transformer'' be limited to transformers that supply loads that are composed of at least 75 percent power electronics. *Id.*

In the May 2019 NOPR, DOE stated that the definition of ''rectifier transformer'' is not intended to cover a large number of transformers intended for general power service; and that linking the definition to a percentage of supply load from power electronics would be insufficient to designate a distribution transformer because it may not be possible for a manufacturer to know in advance what fraction of a distribution transformer's load will include power electronics. 84 FR 207054, 20708. Based on further review of industry testing standards and available manufacturer literature, DOE further stated that it was unable to identify physical attributes that could be used to reliably identify rectifier transformers. *Id.*

DOE requested comment on whether the current definitions of rectifier transformer and drive transformer are sufficiently specific; the level of technical similarity between the two types of transformers; and whether any physical or electrical properties could be used to reliably identify rectifier transformers.

DOE received written comments from CDA and HVOLT stating that defining rectifier transformers as having multiple output windings could be a reasonable addition. (CDA, No. 29 at p.1; HVOLT No. 27 at p. 89) DOE notes that the current definition already specifies that rectifier transformers can have ''one or more'' output windings. 10 CFR 431.192.

CDA and HVOLT also stated that small drive transformers could meet energy conservations standards, but that larger drive transformers are more complicated and would have a more difficult time meeting standards. (CDA, No. 29 at p.1–2; HVOLT No. 27 at p. 89) While smaller drive transformers may be able to meet energy conservation standards, the statutory definition for distribution transformer excludes any transformer that is designed to be used in a special purpose applications and is unlikely to be used in general purpose applications, and specifies drive transformers as such an example. 42 U.S.C. 6291(35)(b)(ii).

NEMA commented that the current definition for both rectifier transformer and drive transformer are sufficient. (NEMA, No. 30 at p.2).

Having considered these comments from interested parties, DOE remains unaware of any industry definition or physical features that would better define either rectifier transformers or drive transformers.

Therefore, DOE makes no changes to the definitions of ''rectifier transformer'' and ''drive transformer'' in this final rule. Both varieties of equipment remain excluded from energy conservation standards and are therefore excluded from the scope of the test procedure (in accordance with the amendment discussed in section III.A of this final rule specifying that the scope of the test procedure is limited to the scope of the distribution transformers that are subject to energy conservation standards). However, as stated in the April 2006 Final Rule, DOE narrowly construes the exclusions from the definition of ''distribution transformer.'' DOE will also take appropriate steps, including enforcement action if necessary, if any manufacturer or other party erroneously invokes one of the exclusions as a basis for marketing a transformer that is a ''distribution transformer,'' but does not meet DOE standards. Moreover, to the extent transformers that do fall within the exclusions begin to be marketed for standard distribution applications, or find widespread use in such applications, DOE will examine whether re-defining the relevant exclusions is warranted. *See* 71 FR 24979.

2. New Definitions

In the May 2019 NOPR, DOE proposed and sought comment on definitions for the terms ''per-unit load,'' ''terminal,'' and ''auxiliary device.'' 84 FR 20704, 20708–20709. These terms are referenced in the DOE test procedure but are not currently defined in the regulatory text. The following sections discuss comments received regarding each of these terms and the definitions established in this final rule.

a. Per-Unit Load

Distribution transformers are regularly operated at capacities other than the capacity listed on a distribution transformer's nameplate (*i.e.,* the rated load). In general, distribution transformers are loaded substantially below their rated load. DOE's current test procedure and energy conservation standards for distribution transformers use various terms to refer to operating or testing a distribution transformer at a capacity other than the rated load, including ''percent load,'' ''percent of nameplate-rated load,'' ''percent of the rated load,'' or ''per unit load level.'' 10 CFR 431.192, 10 CFR 431.196, and appendix A. DOE proposed to consolidate the usage of these various terms into a single term, ''per-unit load'' (''PUL'') in all instances identified. 84 FR 20704, 20709. DOE also proposed to define ''per-unit load'' to mean the fraction of rated load. *Id.*

Howard, CDA, and HVOLT supported the proposed term per-unit load. (Howard, No. 32 at p.1; CDA, No. 29 at p.2; HVOLT, No. 27 at p. 89) DOE did not receive any comments against its proposed definition for per-unit load or its proposal to consolidate all references to partial loading into a single per-unit load term. In order to improve the readability of the test procedure, DOE is adopting the proposed definition for per-unit load at 10 CFR 431.192. DOE is also consolidating all references to partial load operation in 10 CFR 431.192, 10 CFR 431.196, and appendix A to the defined ''per-unit load'' term.

b. Terminal

In the May 2019 NOPR, DOE proposed to clarify that load and no-load loss measurements should be taken only at the distribution transformer terminals, as discussed in section III.F.3. As such, DOE proposed to define ''terminal'' to mean ''a conducting element of a distribution transformer providing electrical connection to an external conductor that is not part of the transformer.'' 84 FR 20704, 20709. This definition is based on, but not identical to, the definition for ''terminal'' in IEEE C57.12.80–2010,[10] ''IEEE Standard

[10] IEEE C57.12.80–2010 is currently listed as ''inactive-reserved'' which means that this standard is ''. . . removed from active status through an administrative process for standards that have not undergone a revision process within 10 years.'' (*See* Continued

Terminology for Power and Distribution Transformers.'' IEEE C57.12.80–2010 defines terminal as ''(A) A conducting element of an equipment or a circuit intended for connection to an external conductor. (B) A device attached to a conductor to facilitate connection with another conductor.''

Howard commented in agreement with the proposed definition. (Howard, No. 32 at p.1) NEMA, CDA and HVOLT preferred DOE to adopt the IEEE C57.12.80–2010 definition of ''terminal'' directly. (NEMA, No. 30 at p. 2; CDA, No. 29 at p. 2; HVOLT, No. 27 at p. 90).

DOE has reviewed the IEEE definition and while part ''(A)'' is similar to the definition proposed in the May 2019 NOPR, part ''(B)'' does not clarify that the terminal needs to be external. While adoption of industry-developed language would promote further consistency between the DOE test procedure and the industry testing standards, DOE is concerned that the IEEE definition could be understood to exclude busbar losses in testing of distribution transformers because part (B) of the IEEE definition does not specify that a terminal is for connection to an external conductor. A manufacturer could interpret terminal to be any conducting element within the distribution transformer, including a conducting element between the busbar and the windings. As a result, DOE is adopting the definition of ''terminal'' proposed in the May 2019 NOPR at 10 CFR 431.192 as ''a conducting element of a distribution transformer providing electrical connection to an external conductor that is not part of the transformer.''

c. Auxiliary Device

Section 4.5.3.1.2 of appendix A specifies that during testing, ''measured losses attributable to auxiliary devices (*e.g.,* circuit breakers, fuses, switches) installed in the transformer, if any, that are not part of the winding and core assembly, may be excluded from load losses measured during testing.'' DOE has received inquiries from manufacturers regarding whether certain other internal components of distribution transformers are required by the DOE test procedure to be included in the loss calculation, or whether they are considered an auxiliary device. In the May 2019 NOPR, DOE proposed to address the prior industry questions and establish a definition of the term ''auxiliary device'' based on a specific list of all components and/or component functions that would be considered auxiliary devices and, therefore, be optionally excluded from measurement of load loss during testing. 84 FR 20704, 20709.

The auxiliary device examples listed at section 4.5.3.1.2 of appendix A (circuit breakers, fuses, and switches) all provide protective function, but do not directly aid the transformer's core function of supplying electrical power. Additionally, the term ''device'' indicates a localized nature, rather than a diffuse system or property of the transformer.

DOE proposed to define ''auxiliary device'' to mean ''a localized component of a distribution transformer that is a circuit breaker, switch, fuse, or surge/lightning arrester.'' DOE requested comment on the proposed definition, if any components needed to be added or removed from the listed auxiliary devices, and whether it is appropriate to include functional component designations as part of a definition. *Id.*

CDA and HVOLT stated that the proposed definition was adequate. (CDA, No. 29 at p.2; HVOLT, No. 27 at p. 90) Howard commented that the four components listed are sufficient and a functional designation is not needed. (Howard, No. 32 at p.1) NEMA commented that the current definitions are adequate and that it is not necessary to define auxiliary device. (NEMA, No. 39 at p.2) NEMA did not specify what, if any, aspects of the proposed definition would be inadequate. Moreover, prior inquiries from industry indicate that the definition of ''auxiliary device'' would benefit from further detail. DOE did not receive any comment suggesting that the proposed definition is inadequate. DOE is adopting the definition of auxiliary device in this final rule as proposed.

3. Updated Definitions

a. Low-Voltage Dry-Type Distribution Transformer

EPCA defines a ''low-voltage dry-type distribution transformer'' as ''a distribution transformer that—(1) Has an input voltage of 600 volts or less; (2) is air-cooled; and (3) does not use oil as a coolant.'' 42 U.S.C. 6291(38).

In the May 2019 NOPR, DOE proposed to update the definition for ''low-voltage dry-type distribution transformer'' by replacing the term ''oil'' with ''insulating liquid'' within the definition, in conjunction with DOE's proposal to consolidate multiple terms to ''insulating liquid,'' as described in section III.B.2. 84 FR 20704, 20709. DOE proposed this update to reflect that the term is inclusive of all insulating liquids, including those identified in IEEE C57.12.90–2015. *Id.*

Howard, CDA, and HVOLT generally supported using the broader term ''insulating liquid'' rather than ''oil.'' (Howard, No. 32 at p. 1; CDA, No. 29 at p. 2; HVOLT, No. 27 at p.91) NEMA recommended harmonizing the definition with the definition provided in IEEE C57.12.80–2010. (NEMA, No. 30 at p. 3) IEEE defines a ''low-voltage dry-type distribution transformer'' to mean ''a distribution transformer that—(1) Has an input voltage of 600 volts or less; (2) Has the core and coil assembly immersed in a gaseous or dry-compound insulating medium.''

Of the three components of EPCA's definition of ''low-voltage dry-type distribution transformer'', the first component (''Has an input voltage of 600 volts or less'') was not proposed for revision by either the May 2019 NOPR or by commenters. 42 U.S.C. 6291(38). This first component of the definition is left unchanged by this final rule.

Whereas the first component of the definition addresses the ''low-voltage'' portion of term ''low-voltage dry-type distribution transformer'', the second and third components (''is air-cooled''; ''does not use oil as a coolant'') combine to describe the manner in which LVDTs dissipate heat and collectively address the ''dry-type'' portion of the term. The comment from NEMA (suggesting that DOE amend the definition to reference the core and coil assembly being ''immersed in a gaseous or dry-compound insulating medium'') indicates that industry generally considers the descriptors ''air cooled; does not use oil as a coolant'' to be synonymous with ''immersed in a gaseous or dry-compound insulating medium.'' The revision suggested by NEMA would also be consistent with DOE's terminology for addressing ''dry type'' in the definition of ''medium-voltage dry-type distribution transformer'', which DOE defines as a distribution transformer in which the core and coil assembly is immersed in a gaseous or dry-compound insulating medium, and which has a rated primary voltage between 601 V and 34.5 kV. 10 CFR 431.192.

After further consideration of the May 2019 NOPR proposal, and consideration of comments from interested parties in response to that proposal, this final rule revises the definition of ''low-voltage dry-type distribution transformer'' to mean ''a distribution transformer that has an input voltage of 600 volts or less and has the core and coil assembly immersed in a gaseous or dry-

www.standard.iee.org). Given that the standard has not been superseded and is not listed as inactive-withdrawn, DOE is continuing to consider it the current industry standard on standard terminology for power and distribution transformers.

compound insulating medium.'' This revised wording harmonizes with the industry definition and implements consistent terminology across both varieties of dry-type distribution transformers (*i.e.,* low-voltage and medium-voltage).

b. Reference Temperature

The reference temperature is the temperature at which the transformer losses must be determined, and to which such losses must be corrected if testing is performed at a different temperature. As currently defined at 10 CFR 431.192, ''reference temperature'' means 20 °C for no-load loss, 55 °C for load loss of liquid-immersed distribution transformers at 50 percent load, and 75 °C for load loss of both low-voltage and medium-voltage dry-type distribution transformers, at 35 percent load and 50 percent load, respectively.

In the May 2019 NOPR, DOE proposed to update the definition for ''reference temperature'' by removing references to the numerical temperature values required for certification with energy conservation standards. 84 FR 20704, 20709. DOE proposed to retain the conceptual definition of reference temperature and to include in appendix A the numerical temperature values for certification with energy conservation standards. The updated definition would allow use of the term reference temperature outside the context of conditions required for certification with energy conservation standards (*i.e.,* voluntary representations at additional temperature values, as described in section III.D.2.b). DOE proposed ''reference temperature'' to mean the temperature at which the transformer losses are determined, and to which such losses must be corrected if testing is performed at a different temperature.

Howard and NEMA both supported the updated definition. (Howard, No. 32 at p. 1; NEMA, No. 30 at p. 3).

CDA and HVOLT commented that the reference temperature for ambient has been used throughout the industry as 20 °C and that letting that number float to other reference temperatures would be confusing to industry. (CDA, No. 29 at p. 2; HVOLT, No. 27 at p. 91).

The reference temperature in the test procedure does not necessarily refer to the ambient temperature, because testing can be performed at a different temperature, with the results corrected to reflect testing at the defined reference temperature. DOE did not propose changes to any of these values for the purpose of certification with energy conservation standards.

The updated definition does not specify particular temperature values in order to accommodate the use of the term in a context other than only the conditions required for certification and compliance, *i.e.,* voluntary representations of efficiency at temperatures or PULs different from those specified in appendix A. For example, a manufacturer voluntarily representing efficiency at 100 percent PUL would correct to a reference temperature that is reflective of the distribution transformer temperature rise at 100 percent PUL.

DOE is adopting the updated definition of ''reference temperature'' in 10 CFR 431.192 as proposed.

D. Per-Unit Load Testing Requirements

The efficiency of distribution transformers varies depending on the PUL at which the distribution transformer is operated. DOE's energy conservation standards for distribution transformers at 10 CFR 431.196 prescribe the PUL at which the efficiency of the distribution transformer must be determined and certified to DOE (*i.e.,* the ''standard PUL''). The standard PUL is intended to represent the typical PUL experienced by in-service distribution transformers over their lifetime. For liquid-immersed distribution transformers and medium-voltage dry-type distribution transformers, the equipment efficiency is certified at a standard PUL of 50 percent. For low-voltage dry-type distribution transformers, the efficiency is certified at a standard PUL of 35 percent. These values were adopted in the April 2006 Final Rule from NEMA TP 2–1998. 71 FR 24972.

As described previously, appendix A does not require testing of the distribution transformer at the standard PUL; rather, the standard PUL is required only for certification of efficiency. Testing can be performed at any PUL, with the results mathematically adjusted to reflect the applicable standard PUL. Section 5.1 of appendix A provides equations to calculate the efficiency of a distribution transformer at any PUL based on the testing of the distribution transformer at a single PUL. Current industry practice is to test at 100 percent PUL and mathematically determine the efficiency at the applicable standard PUL. (NEMA, No. 30 at p. 4).

The efficiency of distribution transformers over the duration of its lifetime and across all installations cannot be fully represented by a single PUL. A given transformer may be highly loaded or lightly loaded depending on its application or variation in electrical demand throughout the day. DOE has previously acknowledged that distribution transformers may experience a range of loading levels when installed in the field. 78 FR 23336, 23350 (April 18, 2013).

DOE previously acknowledged that the majority of stakeholders, including manufacturers and utilities, support retention of the current testing requirements; and DOE determined that its existing test procedure provides results that are representative of the performance of distribution transformers in normal use. *Id.* DOE further determined that potential improvements in testing precision that might result from testing at multiple PULs would be outweighed by the complexity and the burden of requiring testing at different loadings depending on each individual transformer's characteristics. *Id.*

In the May 2019 NOPR, DOE stated that it had considered (1) revising the single standard PUL [11] to a multiple-PUL weighted-average efficiency metric, (2) revising the single standard PUL to an alternative single test PUL metric that better represents in-service PUL, or (3) maintaining the current single test PUL specifications. 84 FR 20704, 20714. DOE tentatively determined that the range of in-service PUL is diverse, and that the available information describing in-service PUL is inconclusive. *Id.* DOE was unable to show that any alternative standard PUL(s) would be more representative than the current standard PUL and therefore did not propose an amendment of the standard PULs. *Id.* DOE proposed, however, to allow for voluntary representations to be made at PULs other than the standard PUL. *Id.*

The following sections summarize comments received on each of these considerations, as well as DOE's responses and conclusions.

1. Multiple-PUL Weighted-Average Efficiency Metric

In the past, DOE has considered a multiple-PUL efficiency metric in contemplating whether a weighted-average efficiency metric composed of efficiency at more than one PUL may better reflect how distribution transformers operate in service. 84 FR 20704, 20713. In the May 2019 NOPR, DOE expressed concern that a multi-

[11] In the May 2019 NOPR, DOE used the term ''test PUL'' to refer to ''standard PUL'' as used in this final rule. The term ''standard PUL'' better reflects that this is referring to the PUL at which the energy efficiency must be determined for the purpose of complying with the energy conservation standards at 10 CFR 431.196. As described previously in this document, testing can be performed at any PUL, with the results corrected to the standard PUL.

PUL metric could increase burden on manufacturers and create challenges in consumer education without being more representative of in-service PULs than the current metric. *Id.*

The Efficiency Advocates suggested that DOE request transformer loading data from IEEE's Transformer Committee to analyze the empirical data describing PUL variation. (Efficiency Advocates, No. 34 at p. 2) The Efficiency Advocates, asserted that the IEEE data shows a wide variation in PUL and that DOE should consider a weighted average PUL efficiency metric in the DOE test procedure. (Efficiency Advocates, No. 34 at p. 2).

DOE has considered a metric based on a weighted average of a transformer's efficiency at multiple different PULs. Different weighting schemes are possible. For example, the measured efficiencies could be weighted by the fraction of operating hours expected at each PUL over the lifecycle of a distribution transformer.

Generally, distribution transformer losses are presented within the industry as consisting of no-load losses, which are approximately constant with PUL, and load losses, which scale nearly quadratically with PUL. Under that set of mathematical assumptions, any particular multi-PUL metric [12] could alternatively be represented by a single-PUL metric that would yield the same efficiency value. In other words, any multi-PUL metric would be replaceable by a certain single-PUL metric. Given this, DOE finds no advantage in adopting a multi-PUL metric for distribution transformers. A multi-PUL metric would represent a slightly more complex way of arriving at the same result that could be derived from a carefully chosen single-PUL metric. As a result, DOE is not adopting a multi-PUL metric for distribution transformers in this final rule.

2. Single-PUL Efficiency Metric

As stated previously, DOE requires distribution transformers' efficiency to be certified at a standard PUL of 50 percent for liquid-immersed distribution transformers and medium-voltage dry-type distribution transformers and 35 percent for low-voltage dry-type distribution transformers. 10 CFR 431.196.

In the May 2019 NOPR, DOE stated that it had considered revising the single standard PUL to an alternative single test PUL that better represents in-service PUL. 84 FR 20704, 20714. DOE tentatively determined that the range of in-service PUL values is diverse, and that the available information describing in-service PUL is inconclusive. *Id.* DOE was unable to conclude that any alternative standard PUL(s) would be more representative than the current standard PUL and, therefore, did not propose to amendment the standard PULs. *Id.*

In response to the May 2019 NOPR, DOE received comments arguing both for and against revising the single-PUL metric; these are discussed in detail in sections III.D.2.a and III.D.2.b. These comments comport with the idea that distribution transformers' in-service PULs reflect diverse operating conditions. After considering the comments brought forward by stakeholders and discussed in sections III.D.2.a and III.D.2.b. DOE has concluded that revising the PUL is not justified at this time for two reasons.

First, there is significant long-term uncertainty regarding what standard PUL would correspond to a representative average use cycle for a distribution transformer given their long lifetimes.[13] The publicly available data effectively amounts to a single year from a few distribution transformer customers. Given the uncertainty associated with future distribution transformer loading, DOE is unable to conclude with certainty that a given alternative single-PUL efficiency metric is more representative than the current standard PUL.

Second, given the uncertainty of future loading distributions, there may be greater risk in selecting too low a standard PUL than too high a standard PUL for two reasons. First, the quadratic nature of load loss means that absolute power consumption grows more quickly on the high side of the standard PUL than on the low side. Second, divergence of the costs associated with different categories of loss means that there is greater risk associated with selecting too low a standard PUL than too high.

Accordingly, in this final rule, DOE is maintaining the current standard PUL specifications. DOE is centralizing the PUL specifications in appendix A, as discussed in section III.F.1.

DOE considered several factors in determining not to revise the current standard PUL requirements in this final rule. In section III.D.2.a, DOE reviews publicly available in-service PUL data. In sections III.D.2.b and III.D.2.c, DOE considers uncertainty in estimates of future load growth, its effects on distribution transformers' in-service PULs, and the respective risks associated with both under- and overestimating actual future in-service PULs.[14]

a. Publicly Available Transformer Load Data

In response to the May 2019 NOPR, the Efficiency Advocates suggested that DOE use IEEE's Advanced Meter Information (''AMI'') data to inform the PUL rulemaking. (Efficiency Advocates, No. 34 at p. 1) Citing IEEE's Distribution Transformer Subcommittee Task Force's (''*IEEE–TF*'') estimates of average in-service PUL for medium-voltage, liquid-filled transformers, the Efficiency Advocates suggest in-service PULs are significantly lower than the current standard PULs. (Efficiency Advocates, No. 34 at p. 2) The Efficiency Advocates recommend, if DOE does not base its analysis on AMI data, that DOE use PUL values of 35 percent for liquid-immersed transformers, 25 percent for low-voltage dry-type distribution transformers, and 38 percent for medium-voltage dry-type distribution transformers. (Efficiency Advocates, No. 34, at pp. 2–3).

Cargill commented that the *IEEE–TF* data suggests average annual loading is less than 30 percent of the ''Peak Annual Load''. (Cargill, No. 28 at p. 1) Cargill stated that even in the most conservative case of peak load equaling nameplate load, the resulting average PUL would be less than 30 percent. (Cargill No. 28 at p. 1) NEMA commented that it is not aware of any changes in the field that would justify modifying the current PUL levels. (NEMA, No. 30 at p. 4).

DOE examined the data made available through *IEEE–TF*.[15] All of the data available through the *IEEE–TF* is for liquid-immersed distribution transformers; DOE did not separately receive updated loading data for LVDTs or MVDTs.

DOE has identified several limitations and questions regarding the data made available through the *IEEE–TF*. First and foremost, none of the datasets of AMI data referred to by the Efficiency Advocates are measured transformer loads, rather they are samples of customer load connected to specific transformers. Additionally, each dataset

[12] Specified as a set of any number of pairs of PUL values and weighting coefficient at that PUL.

[13] DOE determined in the April 2013 ECS Final Rule as having an average lifespan of 32 years, and in many cases they may have an in-service lifetime that is significantly longer. 78 FR 23336, 23377.

[14] *See: Section 2.3 of Chapter 2. Analytical Framework, Comments from Interested Parties, and DOE Responses* of the Prelim Technical Support Document (TSD) at Docket No. EERE–2019–BT–STD–0018–0022.

[15] *See: grouper.ieee.org/groups/transformers/subcommittees/distr/EnergyEfficiency/F20-DistrTransfLoading-Mulkey.pdf.*

presented during the *IEEE–TF* is a sample of customers' AMI data (*i.e.,* not a complete population of distribution transformer load data), and each carries questions regarding the sampling methodology, representativeness, and completeness. DOE does not know what criteria were used to select the sample from each existing population of utility customers. Further, each data set was also incomplete in terms of missing meter readings, non-sequential metering periods, or missing unmetered loads (for example, exterior building lighting, utility owned equipment, and street lighting are usually on separate unmetered tariffs [16]). These unmetered loads, on separate unmetered tariffs, would not be accounted for in the AMI data, and would produce the effect of underestimating in-service PUL for a given transformer.

DOE examined the largest individual sample of data, from Dominion Energy, Inc., which consisted of a year of hourly and sub-hourly readings for roughly 60,000 AMI meters connected to distribution transformers aggregated into zip codes for parts of Virginia and North Carolina.[17] After removing data from AMI meters that were incomplete, or that had the quality issues highlighted in the presentation to the *IEEE–TF* (loads with peak-loads that were several times higher than the connected transformers capacity), DOE found that the average root mean square (RMS) load, as a function of transformer nameplate capacity, over the year in question (2018) was substantially higher than the 10 percent mode value presented to the *IEEE–TF.* DOE found that average RMS in-service PUL for the transformers subject to the DOE test procedure and energy conservation standards was 27.8 percent.[18]

After reviewing the *IEEE–TF* AMI data, DOE agrees with the Efficiency Advocates and Cargill that the current data indicates that the average, current, in-service, liquid-immersed distribution transformer loading is lower than the standard PUL. However, the data also indicates that distribution transformers operate over a diverse range of operating conditions. The data shows that a single customer does not operate a distribution transformer at a single constant PUL. Further, a given distribution transformer model may be used at different PULs by different customers. The realities of the typical range of operations, and issues of data quality and sample completeness raise uncertainties regarding the representativeness of the average PUL values presented by the *IEEE–TF.*

DOE also notes that while the *IEEE–TF* AMI data provides valuable insight into the in-service PUL of liquid-immersed distribution transformers, no equivalent, publicly available data has been presented for medium-voltage and low-voltage dry-type distribution transformers.

Another complicating factor in the representativeness of the currently available data is that the *IEEE–TF* AMI data only covers a single year of distribution transformer lifespans. Distribution transformers have lifespans of several decades and as such, DOE needs to consider not only the diversity of operating conditions that distribution transformer currently experience but the entire range of operating conditions a distribution transformer would experience in its lifespan. Additionally, most of the available data are from similar geographies, on the Atlantic coast, which would experience similar climatic sensitivities, which is not representative of the Nation as a whole. Stakeholders identified several possible factors that could significantly impact distribution transformer loading in the short to medium term, as discussed in section III.D.2.b.

b. Load Growth Uncertainties

DOE received several comments from stakeholders in response to the May 2019 NOPR on the topic of future load growth on distribution transformers. Cargill supported maintaining the current standard PUL, asserting that as future transformer loads increase, increased transformer efficiency could be realized due to conventional core steel having a peak efficiency between 45 and 55 percent PUL. (Cargill, No. 28 at p. 1) Cargill also suggested that utilities are increasingly considering overloading transformers during peak demand with the objective of replacing larger mineral-oil-filled transformers with smaller, cheaper transformers. Such an approach, Cargill asserts, could increase average loading to 50 percent and support retaining the current standard PULs. (Cargill, No. 28 at p. 2) The Efficiency Advocates commented that increased adoption of photovoltaic generation (''PV'') will depress peak demand, as it has done in California. The Efficiency Advocates also commented that increasing adoption of electric vehicles (''EVs'') is unlikely to contribute to peak demand and load growth because it is in utilities' interest to encourage off-peak charging. (Efficiency Advocates, No. 34 at p. 3) Further, the Efficiency Advocates recommended against DOE's continued use of a 1 percent average annual increase, claiming that based on past experience and future projections, load growth of this magnitude is unlikely. (Efficiency Advocates, No. 34 at pp. 4) Finally, the Efficiency Advocates asserted that increases in demand due to population growth will be met with the installation of new transformers, rather than increasing loads on existing transformers. (Efficiency Advocates, No. 34 at p. 2–3).

HVOLT and CDA commented that standard PUL changes are not needed right now, but that EV charging in the future may increase loading. (CDA, No. 29 at p. 89; HVOLT, No. 27 at p. 94).

Load growth has always been, and continues to be, difficult to predict. Stakeholders disagreed as to what future distribution transformer loading would be expected. While *IEEE–TF* data suggests that the current in-service PUL is lower than the standard PUL, the extent to which distribution transformer load will change over time is unclear. Distribution transformers were evaluated in the April 2013 ECS Final Rule as having an average lifespan of 32 years, and in many cases they may have an in-service lifetime that is significantly longer. 78 FR 23336, 23377. The long lifetime of distribution transformers means that many will operate through multiple economic, social, or climate-driven events that could affect the average in-service PUL on individual transformers.

In response to Cargill, while many conventional core steel transformers have a peak efficiency between 45 and 55 percent, this is not generally the case across the entire market and may in part be driven by the 50 percent standard PUL specified in the DOE test procedure. Given an alternative standard PUL, conventional core steel transformers could be designed with peak efficiencies at other values. Further, while some utilities may be considering overloading transformers as standard operating practice and could therefore replace larger distribution transformers with smaller distribution transformers, thereby increasing the in-service PUL of these distribution transformers, DOE does not have any data to substantiate Cargill's claim that this practice is actually occurring or is expected to occur.

In response to the Efficiency Advocates, DOE generally agrees that PV generation as a resource at the level of the transmission grid can both reduce

[16] J. Triplett, S. Rinell and J. Foote, ''*Evaluating distribution system losses using data from deployed AMI and GIS systems,*'' 2010 IEEE Rural Electric Power Conference (REPC), 2010, pp. C1–8, doi: 10.1109/REPCON.2010.5476204.

[17] Zip codes were used to aggregate customer AMI data to anonymize the data.

[18] *See:* Chapter 7. Energy Use Analysis of the Prelim TSD at Docket No. EERE–2019–BT–STD–0018–0022.

the overall generation required to serve a population and have potential impacts of reducing peak-demand in areas where there is enough solar resource to do so. However, when considered at the level of the load(s) being served by individual distribution transformers, PV generation (or other demand-side generation) will generally reduce the load on the transformer only by the quantity of energy consumed on the secondary-service side, (*i.e.,* the customer connected side), of the transformer. Unless the PV generation is not grid-tied, any surplus energy being transformed from secondary-service voltages to primary-service voltages and fed back into the grid for distribution would contribute to the average load of the transformer. Depending on the quantity of surplus energy being fed back into the grid, PV generation could have the effect of either decreasing or increasing the average PUL on an individual distribution transformer. Further, if surplus energy is fed back into the grid during peak times, it could have the impact of increasing both peak load and average load. A recent study by National Renewable Energy Laboratory (''NREL'') and Los Angeles Department of Water and Power (''LADWP''), *Los Angeles 100% Renewable Energy Study (''LA100''),* researching the needs to serve the greater city of Los Angeles with 100 percent renewable energy, estimated that 80 percent of existing distribution feeders would need to be upgraded due to occurrences of one or more overloading violations with the connected transformers.[19] Integrating PV or other distributed-generation in a dispatchable manner is a technically complex task, and at the transmission level can reduce overall electricity demands; however there is also the potential that loads may rise on some distribution circuits (and connected distribution transformers) to meet these transmission reductions.

The Efficiency Advocates' claim that EV impacts on peak electricity demand and transformer loads may be small, given the assertion that it is in the electric utility's interest to promote off-peak charging, is incomplete. The Efficiency Advocates cited an article in support of their assertion that ''at a macro scale, EVs appear to pose only a modest burden on the electric grid''.[20] However, this position oversimplifies the relationship between connected loads, the distribution grid, and transmission grid. The article cited by the Energy Advocates cautions that at a micro scale, EVs represent a significant addition to traditional household loads; and further states that the addition of a level 2 residential EV charging station contributes a load similar to an additional house on the grid.[21]

While there are likely benefits to promoting off-peak charging, or other types of structured charging schemes, EV charging is difficult to predict and model because EV adoption is still in the early stages. While some utility programs have been successful at shifting EV loads from peak to off-peak times using time-of-use rates or specific EV charging electricity tariffs, offsetting system peak capacity demands, the additional load required to charge an EV during non-peak times will still contribute to the overall average transformer PUL. Analysis conducted for the *LA100* study indicates, under the ''moderate'' projection, that electrical demand for transportation will be one of the largest contributors to distribution load growth over their analysis period (2020 through 2045).[22] The *LA100* study addresses the load impacts on utility distribution systems, which would be served by liquid-immersed medium-voltage distribution transformers, it does not address the potential impacts to commercial and industrial customers who deploy dry-type distribution transformers. The impact of EV driven load growth on dry-type distribution transformers could also be significant, particularly if EVs are charged on circuits without upgrades to the serving low- or medium-voltage dry-type distribution transformers.

In response to the September 2017 RFI, the Efficiency Advocates challenged DOE's assertion that the record supports a 50 percent PUL for liquid-immersed distribution transformers (on the basis that increasing future load growth at the rate of one percent per-year would result in in-service PULs that would eventually converge with the test standard PUL over time was calculated was incorrectly). In the September 2017 RFI DOE asserted that with a one-percent future growth rate over time, then-current observed RMS PUL values would approximately converge to the standard PUL values. 82 FR 44347, 44349. In response to the load growth assertions from the Efficiency Advocates, DOE examined the trend in sales of electricity to customers made available by the Annual Energy Outlook (AEO) in its Electric Power Monthly periodical.[23] DOE first examined the time period highlighted by the Efficiency Advocates and confirms that 2018 was a year in which sales were much higher than in the preceding period from 2011 through 2017. DOE notes that while 2018 had the greatest year-on-year growth over this period, there were other years with positive growth, and the average year-on-year growth for the period between 2011 through 2018 was 0.4 percent. DOE also finds that the time period highlighted by the Efficiency Advocates is not sufficient for this analysis given that the average in-service lifetime for distribution transformers is 32 years. As such, DOE takes a longer view of the trend of available data when considering the impacts of load growth. When examining the 10-year rolling average of year-on-year growth for the period 2010 through 2020, it can be observed that sales of electricity increased for every period, except for the periods ending in 2017 and 2020, with an average year-on-year increase of 0.3 percent.[24]

As mentioned, the Efficiency Advocates assert that future growth in electricity sales will be driven by population growth, which tends to cause grid expansion and the installation of new transformers, rather than to increase loads on existing transformers. (Efficiency Advocates, No. 34 at p. 2–3) DOE partially agrees with the Efficiency Advocates, that load growth from new construction would be met with new transformers. DOE must consider that the additional factors that drive load growth (*e.g.,* weather events, expanding populations, increased electrification), impact all connected distribution transformers, not just those installed to provide service to new construction, and therefore must consider the effect of load growth's

[19] Palmintier, Bryan, Meghan Mooney, Kelsey Horowitz, *et al.* 2021. ''Chapter 7: Distribution System Analysis.'' In the Los Angeles 100% Renewable Energy Study, edited by Jaquelin Cochran and Paul Denholm. Golden, CO: National Renewable Energy Laboratory. NREL/TP–6A20–79444–7. *www.nrel.gov/docs/fy21osti/79444-7.pdf.*

[20] J. Coignard, P. MacDougall, F. Stadtmueller and E. Vrettos, ''Will Electric Vehicles Drive Distribution Grid Upgrades?: The Case of California,'' in IEEE Electrification Magazine, vol. 7, no. 2, pp. 46–56, June 2019, doi: 10.1109/MELE.2019.2908794.

[21] *Ibid.*

[22] Hale, Elaine, Anthony Fontanini, Eric Wilson, *et al.* 2021. ''Chapter 3: Electricity Demand Projections.'' In the Los Angeles 100% Renewable Energy Study, edited by Jaquelin Cochran and Paul Denholm. Golden, CO: National Renewable Energy Laboratory. NREL/TP–6A20–79444–3. *www.nrel.gov/docs/fy21osti/79444-3.pdf.*

[23] Energy Information Administration, Electric Power Monthly, *www.eia.gov/electricity/monthly/.*

[24] Energy Information Administration, {*Electric Power Monthly December 1997,* DOE/EIA–0226(97/12); *Electric Power Monthly December 2011,* DOE/EIA–0226(2011/12); *Electric Power Monthly December 2017; Electric Power Monthly December 2020*}, *www.eia.gov/electricity/monthly/*, See for each of the four listed time periods: Table 5.1. Sales of Electricity to Ultimate Customers: Total by End-Use Sector.

impact on a transformer's typical use cycle.

The Efficiency Advocates requested DOE respond to their comment on the September 2017 RFI, where the Efficiency Advocates challenged DOE's assertion that, for liquid-immersed distribution transformers, future load growth (at the rate of one percent per-year), would result in in-service PULs that would eventually converge with the standard PUL over time, and stated that the in-service PUL was calculated incorrectly. (Efficiency Advocates, 0015 at p. 1) In the September 2017 RFI, DOE asserted that, on average, the initial (first year) RMS PUL for liquid-immersed transformers ranged from 34 and 40 percent for single- and three-phase equipment, respectively, with a one percent annual increase over the life of the transformer to account for connected load growth. This resulted in a lifetime average PUL of 49 and 56 percent for single- and three-phase liquid-immersed transformers, respectively. And that it was consistent with the current test procedure requirements of rating liquid-immersed transformers at 50 percent PUL. 86 FR 44349. After further analysis of the data, DOE agrees with the Efficiency Advocates that the load growth impact on PUL in the September 2017 RFI was incorrectly calculated. DOE agrees the load growth rates needed to support the assertion that the in-service PUL would converge with the standards PUL over the transformers typical lifetime in the September 2017 RFI would need to be greater than the proposed one percent per-year. While the conclusions drawn in the September 2017 RFI cannot be supported, recent market and policy changes since the publication of the RFI indicate that the premise that there are uncertainties and concerns associated with future load growth, continue to be valid.

c. Risks Associated With Current and Future Losses

Given the diversity of conditions under which distribution transformers are currently operated and the uncertainty as to how future changes in connected loads will affect in-service PULs, DOE must consider how a single standard PUL would fare in both circumstances in which it overestimates and underestimates the in-service PUL. As discussed in section III.D.1, a distribution transformer's efficiency is determined as a function of the total losses at the standard PUL. A distribution transformer's total losses at the standard PUL are the sum of its no-load losses and load losses at the standard PUL. No-load losses are approximately constant with the PUL and load losses increase quadratically with PUL.

Every distribution transformer has a PUL for which efficiency peaks, where no-load and load losses happen to be equal. While there is no prescribed PUL at which this must occur, often, as a result of optimizations in the manufacturing process, transformers are most efficient at, or near, the DOE prescribed standard PUL. Distribution transformers that have a peak efficiency at PUL values greater than the average in-service PUL overemphasize load losses and distribution transformers that have a peak efficiency less than the average in-service PUL overemphasize no-load losses relative to transformer designs with equivalent total losses that peak at the in-service PUL. The asymmetry in rate of loss change—the losses rise faster at PULs greater than the standard PUL than they fall at PULs less than the standard PUL—contributes to the conclusion that the risk of selecting a suboptimal standard PUL is greater on the low side than on the high side. Efficiency falls in proportion to the degree to which in-service PUL diverges from standard PUL. Because a lower in-service PUL corresponds (on a single-unit basis) to a lower absolute quantity of energy, however, a given loss of efficiency equates to a greater absolute quantity of energy when the in-service PUL exceeds standard PUL.[25]

As stated in section III.D.2.a, the Efficiency Advocates recommend DOE select a lower standard PUL to better align with the AMI data. (Efficiency Advocates, No. 34, at pp. 2–3) DOE notes that the maximum technologically feasible design options analyzed in the April 2013 Final Rule consist of distribution transformers that have a peak efficiency well below the standard PUL (often times below 20 percent PUL). 78 FR 23337. This indicates that distribution transformers can be built that perform well at both the in-service PULs cited by the Efficiency Advocates and meet efficiency standards at the current standard PUL. Energy savings achieved through the energy conservation standard rulemaking at the current PUL have less of this asymmetric risk because they do not discount load losses to the same degree as a lower PUL.

In addition to considering the energy savings potential of the standard PUL overestimating and underestimating in-service PUL, DOE also considered the financial value of losses to consumers associated with overestimating and underestimating in-service PULs.

i. Peak Coincidence Risks

The Efficiency Advocates suggested that it in the best interest of utilities to pursue programs to mitigate risks related to peak demands. (Efficiency Advocates, No. 34 at p. 3) Demand response programs can help flatten peaks at the grid, distribution, and individual consumer levels. A simplified example is a demand response program which promotes peak-load shifting, wherein utility ratepayers defer or forego electrical consumption during times when the system is peaking. This may have a bottom-up effect of reducing peak power through individual distribution transformers by reducing peak generation. Owners of distribution transformers typically face different costs depending on overall demand, which influences the mix of generation and storage they may deploy to meet the demand. Large electrical consumers (who with electrical utilities generally form the total set of distribution transformer owners), too, face demand-based cost of electrical power. In general, marginal cost of electricity is greater during times of high demand. This carries implications for valuing the losses of distribution transformers. Specifically, load losses will tend to be costlier for the owner of the distribution transformers as proportionally more of them occur during periods of high demand and correspondingly higher energy cost.

By their nature, distribution transformers tend to be ''peak-coincident'', *i.e.,* the peak load on the distribution transformers tends to coincide with peak load on the larger electrical network. That distribution transformer loading peaks to when electrical power costs peak can result in certain distribution transformer customers bearing high operating cost for a small number of peak operating hours. Distribution transformers designed without account of this electrical cost dynamic, optimized for lower in-service PULs, will operate at comparatively low efficiency when the cost of operation is greatest. DOE recognizes that demand response programs can reduce the peak-load impacts. However, because distribution transformers reflect the load patterns of their connected loads, the risks of the high rate of load losses associated with peak coincidence cannot be fully controlled by utilities and are dependent on consumer patterns. Accordingly, DOE needs to maintain a

[25] See: Section 2.3 of Chapter 2. Analytical Framework, Comments from Interested Parties, and DOE Responses of the Prelim TSD at Docket No. EERE–2019–BT–STD–0018–0022.

PUL which adequately addresses both high and low in-service loads.

ii. Serving Future No-Load and Load Losses

In evaluating the financial risk to consumers of the standard PUL over- and underestimating in-service PULs, and given the long lifespans of distribution transformers, DOE needs to consider how future no-load and load losses will be served.

The way in which future electricity generation needs will be met has historically been considered in DOE's ECS analyses. However, to the extent that the choice of metric affects the cost effectiveness and energy consumption (both in the aggregate quantity and the timing of that energy consumption) of consumers, some background on the power grid (the operating site of distribution transformers) is necessary to understand the broader impacts of any metric change. Insofar as purchasers of distribution transformers select on the basis of first cost, manufacturers may attempt to minimize first cost subject to compliance with energy conservation standards. The specific distribution transformer design that minimizes first cost may vary based on the metric it is being evaluated against. Thus, selection of standard PUL may indirectly influence purchase prices and energy consumption of distribution transformers.

In the April 2013 ECS Final Rule, DOE assumed that future power needs for no-load losses would be met by the mix of different baseline generation types in the year of compliance, 2016. 78 FR 23337. At that time, DOE based its analysis on the data available from AEO 2012, which indicated a mix of generation types which was predominantly served by coal at 26 percent, natural gas combined cycle at 19 percent, renewables and natural gas combustion turbines both at 15 percent, with the remainder generation being met by other generation types.[26] DOE projected that future no-load losses generation would be met by new capacity from coal, as it serves predominantly base load, and natural gas and renewables serve a mix of base-, mid-merit and peaking loads.[27] DOE assumed that load losses would be met with simple combustion turbines.[28] This resulted in a cost, in terms of dollars per watt, ($/W) for no-load losses that was higher than the cost of load losses. A contributing factor to this difference is the relatively high overnight capital cost of large coal plants, in terms of dollars per megawatt unit capacity, ($/MW) when compared to other generating types for determining the capacity cost component of the cost of electricity. However, the current AEO 2021 projects a very different mix of generating fuel types, now and into the future, with retiring coal and, to a lesser degree, nuclear generation being displaced by natural gas, in the near-term, and then renewables in future years. These trends are shown in Table III.3. This shift in generating fuels suggests that the future cost associated with no-load losses and load losses will be closer in price than previously estimated as similar generating units are used to meet both no-load and load losses.

TABLE III.3—PROJECTED FRACTION OF GENERATION BY FUEL TYPES FOR CERTAIN YEARS

[Percent of total generation]

Year	Coal (%)		Natural gas (%)		Nuclear (%)		Renewable sources (%)		Other sources (%) *	
AEO	2012 **	2021 †	2012	2021	2012	2021	2012	2021	2012	2021
2010	46		23		20		10		1	
2015	39		26		21		13		1	
2020	40	20	24	40	22	20	13	20	1	0
2025	41	17	24	35	21	18	14	29	1	0
2030	40	16	25	34	21	15	13	34	1	0
2035	40	15	26	33	19	14	14	37	1	0
2040		14		34		13		38		0
2045		12		35		13		39		0
2050		12		35		12		41		0

* Includes the following generation fuel-type categories: Distributed Generation, Generation for Own Use, Petroleum, Pumped Storage/Other.

** Source: U.S. Energy Information Administration, Annual Energy Outlook 2012, Electricity Electric Power Sector Generation (Case Reference case Region United States).

† Source: U.S. Energy Information Administration, Annual Energy Outlook 2021, Electricity Electric Power Sector Generation (Case Reference case Region United States).

As stated previously, in this final rule, DOE is maintaining the current standard PUL specifications. DOE is centralizing the PUL specifications in appendix A, as discussed in section III.F.1.

Further, the test procedure and accompanying energy conservation standards do not preclude manufacturers from optimizing distribution transformer performance at a PUL other than the standard PUL so long as the unit complies with the applicable standard when tested at the standard PUL. While reducing the standard PUL could in certain cases have a positive impact on energy savings, especially for distribution transformers fabricated with low-loss core materials such as amorphous steel, the same energy savings outcome can often be achieved through amending the energy conservation standard for distribution transformers. In other words, the savings associated with a potential reduction of standard PUL is often a byproduct of greater consumer selection of amorphous-based transformers, which by chance tend to both be relatively better at smaller PUL values and also be more efficient in absolute terms. Many of the distribution transformer designs in the accompanying energy conservation standards preliminary engineering analysis with efficiencies above the current standard are optimized to operate at a PUL below 25 percent due to the use of amorphous steel cores, while certifying at the current standard PUL. It is in the accompanying energy conservation standards where details and data related to the efficiency standards of distribution transformers can be fully evaluated under the EPCA requirements that any new or amended energy conservation standard be designed to achieve the maximum improvement in energy or water

[26] Energy Information Administration, Annual Energy Outlook, 2012, *Table 54. Electric Power Projections by Electricity Market Module Region.*

[27] See Chapter 7 of the 2013 final rule TSD, available at *https://www.regulations.gov/document/EERE-2010-BT-STD-0048-0760.*

[28] *Ibid.*

efficiency that is technologically feasible and economically justified. (42 U.S.C. 6316(a); 42 U.S.C. 6295(o)(2)(A)) DOE is also permitting voluntary representations of efficiency at additional PULs so that manufacturers can communicate to customers the efficiency of their distribution transformers at various service PULs, as discussed in section III.D.3. Additionally, voluntarily representations at additional PULs may be relied upon by voluntarily programs such as ENERGY STAR®, which publishes a buying guide[29] to assist distribution transformer purchasers that may save energy and cost in the context of the purchasers' specific PUL distribution.

Finally, DOE notes that the observable data and trends indicate that there are ongoing changes in policies, consumer demand, and data availability which are beginning to have an impact on the distribution transformer operations. These changes present uncertainties with regard to distribution transformer loading, and DOE will continue to evaluate changes in the market and in operation that may require consideration in future test procedure evaluations.

3. Voluntary Representations of Efficiency at Additional PULs

In the May 2019 NOPR, DOE proposed amendments to the test procedure to permit manufacturers to make voluntary representations of additional performance information of distribution transformers when operated under conditions other than those required for compliance with the energy conservation standards for distribution transformers at 10 CFR 431.196. 84 FR 20704, 20714. DOE proposed the provisions regarding voluntary representations to help consumers make better purchasing decisions based on their specific installation conditions. Specifically, DOE proposed in a new section 7 of appendix A to specify that manufacturers are permitted to represent efficiency, no-load loss, or load loss at additional PULs and/or reference temperatures, as long as the equipment is also represented in accordance with DOE's test procedure at the mandatory (standard) PUL and reference temperature. When making voluntary representations, best practice would be for the manufacturers also to provide the PUL and reference temperature corresponding to those voluntary representations.

NEMA stated that the current test procedure is already applicable to alternative PULs. (NEMA, No. 30 at p. 4) Howard, CDA, and HVOLT commented that voluntary representations would be useful in examining efficiencies at alternative PULs. (Howard, No. 32 at p. 1; CDA, No. 29 at p. 3; CDA, No. 29 at p. 4; HVOLT, No. 27 at p. 92–94)

As discussed, while the test procedure accommodates testing at any PUL, and correcting the results to reflect any other specified PUL, DOE's energy conservation standards specify standard PULs that must be used to represent the energy efficiency of distribution transformers. 10 CFR 431.196. EPCA prohibits manufacturers from making representations respecting the energy consumption of covered equipment or cost of energy consumed by such equipment unless that equipment has been tested in accordance with the applicable DOE test procedure and such representations fairly disclose the results of that testing. (42 U.S.C. 6314(d)) Accordingly, there is benefit in manufacturers being explicitly permitted to make representations respecting energy consumption at alternative PULs and reference temperatures that may better suit an individual consumer's demands.

For the reason expressed in the May 2019 NOPR and above, DOE is establishing new section 7 of appendix A, which explicitly provides that any PUL and temperature values other than those required for determining compliance can be used for voluntary representations when testing is conducted in accordance with the applicable DOE test procedure. Table III.4 summarizes the applicable PUL and temperature values.

TABLE III.4—SUMMARY OF VOLUNTARY REPRESENTATION

	Mandatory certified values *			Voluntary representations		
	Metric	PUL (percent)	Reference temperature for loead loss (°C)	Metric	PUL (percent)	Reference temperature (°C)
Liquid Immersed	Efficiency	50	55	Efficiency, load loss, no-load loss.	Any	Any.
MVDT		50	75			
LVDT		35	75			

* Efficiency must be determined at a reference temperature of 20 °C for no-load loss for all distribution transformers.

E. Multiple Voltage Capability

Some distribution transformers have primary windings (''primaries'') and secondary windings (''secondaries'') that may each be reconfigured, for example either in series or in parallel, to accommodate multiple voltages. Some configurations may be more efficient than others.

Section 4.5.1(b) of appendix A requires that for a transformer that has a configuration of windings that allows for more than one nominal rated voltage, the load losses must be determined either in the winding configuration in which the highest losses occur, or in each winding configuration in which the transformer can operate. Similarly, section 5.0 of appendix A states that for a transformer that has a configuration of windings that allows for more than one nominal rated voltage, its efficiency must be determined either at the voltage at which the highest losses occur, or at each voltage at which the transformer is rated to operate. Under either testing and rating option (*i.e.,* testing only the highest loss configuration, or testing all configurations), the winding configuration that produces the highest losses is tested and consequently must comply with the applicable energy conservation standard.

[29] United States Environmental Protection Agency. *ENERGY STAR® Guide to Buying More Energy Efficient Distribution Transformers. October 2017. Accessed July 7, 2021. https://www.energystar.gov/sites/default/files/asset/document/Transformers%20Buyer%27s%20GuideFinal10-16-17.pdf.*

The relevant industry test standards, IEEE C57.12.00–2015 and IEEE C57.12.01–2020, direct distribution transformers to be shipped with the windings in series. Therefore, a manufacturer physically testing for DOE compliance may need to disassemble the unit, reconfigure the windings to test the configuration that produces the highest losses, test the unit, then reassemble the unit in its original configuration for shipping, which would add time and expense.

In the May 2019 NOPR, DOE did not propose amending the requirement related to transformers being tested in the configuration that produces the highest losses. 84 FR 20704, 20718. DOE noted that it provides for certification using an alternative efficiency determination method (AEDM), which is a mathematical model based on the transformer design (10 CFR 429.47), and that the availability of an AEDM mitigates the potential cost associated with having to physically test a unit in a configuration other than in its ''as-shipped'' configuration. *Id.*

Howard, NEMA, CDA and HVOLT suggested that transformers be tested in the ''as-shipped'' configuration, which is typically with the windings in series. (Howard, No 32 at p. 1; CDA, No. 29 at p. 3; HVOLT, No. 27 at p. 92; NEMA, No. 30 at p. 6) NEMA commented that the requirement to test in the highest losses configuration is confusing to customers and adds undue burden on manufacturers, whereas industry testing standards have changed to test and ship in highest voltage configurations. (NEMA, No. 30 at p. 6) NEMA claims the burden associated with requiring testing of the configuration with the highest loss is especially unnecessary given that the overwhelming majority of transformers are used in the highest voltage configuration, with less than 5% of transformers in applications other than the ''as-shipped'' configuration. (NEMA, No. 30 at p. 6) NEMA asserted that while it can be hard to generalize the losses associated with less efficient winding configurations, given the variability in application, the losses are typically less than 1% of load losses, and that it has never seen the difference between configurations exceed 2% of load losses. (NEMA, No. 30 at p. 4; NEMA, No. 30 at p. 6) NEMA further asserted that given the minimal efficiency gains in testing in the highest-loss and the relatively small percentage of transformers operated in a configuration other than ''as-shipped'', the burden on manufacturers is not justified. (NEMA, No. 30 at p. 6)

As stated in the May 2019 NOPR, DOE recognizes that testing in the as-shipped condition may be less burdensome for certain manufacturers, but DOE also stated that it does not have data to support NEMA's claim that the ''as-shipped'' configuration would lead to a maximum of 2 percent increase in load losses. 84 FR 20704, 20718. NEMA cited certain example distribution transformers where the load loss increase was 2 percent or less, however, the data is only for a few select distribution transformers and not representative of the industry as a whole. (NEMA, No. 30 at p. 7) In interviews, several manufacturers suggested that in certain extreme cases the difference in efficiency could be much higher than the 2 percent figure cited by NEMA.

Further, even if DOE did have data affirming the 2 percent figure NEMA cited, it would be expected that such a change to the test procedure would require a corresponding change to the energy conservation standards to account for the change in measured load loss values. A change to the energy conservation standards would necessitate certain manufacturers of transformers with multiple windings to re-test and re-certify their performance to DOE.

As explained in the May 2019 NOPR, as an alternative to physical testing, DOE provides for certification using an AEDM, which is a mathematical model based on the transformer design. 10 CFR 429.47. The shipped configuration has no bearing on the AEDM calculation, and an AEDM can determine the highest-loss configuration instantly. DOE notes that most transformers are currently certified using the AEDM and the current burden is therefore less than the commenters asserted for the majority of manufacturers. In interviews, manufacturers suggested that this burden existed only when verifying an AEDM. Further, many distribution transformers are reconfigured using a switch, which minimizes effort required to change winding configurations. NEMA confirmed that there is no burden associated with rewiring when utilizing an AEDM and rather that the benefit to changing to ''as-shipped'' testing is that for higher-volume, single-phase pole mount units manufacturers could continually gauge the ''as-shipped'' performance against the AEDM. (NEMA, Docket No. EERE–2017–BT–TP–0055–0036 at p. 3) While there may be benefits in continually gauging the ''as-shipped'' performance against the AEDM, DOE remains concerned about the magnitude of the increase in load losses for certain distribution transformers.

As a result, DOE is not amending in this final rule the current requirements of section 4.5.1(b) of appendix A (for a transformer that has a configuration of windings that allows for more than one nominal rated voltage, the load losses must be determined either in the winding configuration in which the highest losses occur, or in each winding configuration in which the transformer can operate) and section 5.0 of appendix A (for a transformer that has a configuration of windings that allows for more than one nominal rated voltage, its efficiency must be determined either at the voltage at which the highest losses occur, or at each voltage at which the transformer is rated to operate).

F. Other Test Procedure Topics

In addition to the updates to the DOE test procedure discussed in the preceding sections, DOE also considered whether the existing test procedure would benefit from any further revisions and/or reorganizing. Additional issues are discussed in the following sections.

1. Per-Unit Load Specification

In the May 2019 NOPR, DOE proposed to centralize the PUL specifications, both for the certification to energy conservation standards and for use with a voluntary representation. 84 FR 20704, 20718–20719. Currently, the PULs required for certification to energy conservation standards are specified for each class of distribution transformer at 10 CFR 431.196 and referenced indirectly in multiple locations, including 10 CFR 431.192 (within the definition of reference temperature), section 3.5(a) of appendix A, and section 5.1 of appendix A. DOE proposed to consolidate the PUL specification into one location—a newly proposed section 2.1 of appendix A. Additionally, DOE proposed to provide in the proposed section 2.1 of appendix A that the PUL specification can be any value for purposes of voluntary representations. *Id.* DOE did not receive any comments on these proposed changes and is adopting them in this final rule.

The consolidation enhances readability of the test procedure and more clearly communicates the PUL requirements with respect to certification to energy conservation standards and voluntary representations. The updates do not change the standard PUL requirements with respect to certification to energy conservation standards. Instead, the updates improve clarity with respect to selection of PUL for voluntary representations versus certification to energy conservation standards.

DOE also proposed editorial changes to section 5.1 of appendix A to support the consolidated approach to PUL specification. 84 FR 20704, 20719. Section 5.1 of appendix A provides equations used to calculate load-losses at any PUL. Section 5.1 of appendix A used language that limited its applicability to certification to energy conservation standards only. For example, it referenced the ''specified energy efficiency load level'' (*i.e.,* the PUL required for certification to energy conservation standards) specifically. DOE proposed to generalize the language in this section to reference the PUL selected in the proposed section 2.1. *Id.*

DOE did not receive any comments regarding these proposed editorial changes and is adopting them in this final rule.

2. Reference Temperature Specification

Similar to PUL, DOE proposed to consolidate the reference temperature specifications for certification to energy conservation standards and for the proposed voluntary representations. 84 FR 20704, 20719. The reference temperature specifications for certification to energy conservation standards are defined at 10 CFR 431.192 (as the definition of ''reference temperature''), and are referenced in section 3.5(a) of appendix A and section 4.4.3.3 of appendix A. DOE proposed to consolidate the reference temperature specifications into one location—a newly proposed section 2.2 of appendix A. 84 FR 20704, 20719. Additionally, DOE proposed to describe in the proposed section 2.2 of appendix A that the reference temperature specification can be any value for purposes of voluntary representations. *Id.* DOE did not receive any comments on the proposed changes and is adopting them in this final rule.

Similar to PUL, this consolidation will enhance readability of the test procedure and more clearly communicate DOE's reference temperature requirements with respect to certification to energy conservation standards or voluntary representations. The updates do not change existing reference temperature requirements with respect to certification to energy conservation standards. Instead, the updates improve clarity with respect to selection of reference temperature for voluntary representations versus certification to energy conservation standards.

DOE also proposed editorial changes to sections 3.5 and 4.4.3.3 of appendix A to support the consolidated approach to reference temperature specification. Section 3.5 of appendix A provided reference temperatures for certification to energy conservation standards. DOE has consolidated reference temperature specifications into one location (section 2.2); therefore, DOE has removed the same specification in section 3.5 so that the section is applicable to determine voluntary representations.

Section 4.4.3.3 of appendix A provides the specifications and equations used for correcting no-load loss to the reference temperature. Specifically, the section provides an option for no correction if the no-load measurements were made between 10 °C and 30 °C (representing a ±10 °C tolerance around the 20 °C reference temperature). This tolerance is applicable only for certification to energy conservation standards. For simplicity, DOE proposed no such tolerance for voluntary representations at additional reference temperatures, so that all measured values would be adjusted using the reference temperature correction formula. 84 FR 20704, 20719. Finally, DOE proposed to remove any reference to a reference temperature of 20 °C so that the section would be applicable to determine voluntary representations. *Id.*

DOE did not receive any comments on these proposed changes and is adopting them in this final rule.

3. Measurement Location

DOE proposed to specify that load and no-load loss measurements are required to be taken only at the transformer terminals. 84 FR 20704, 20719. In the May 2019 NOPR, DOE proposed a definition for ''terminal,'' as described in section III.C.2.b of this final rule. DOE notes that section 5.4 of IEEE.C57.12.90–2015 and section 5.6 of IEEE C57.12.91–2020 specify terminal-based load-loss measurements. In addition, section 8.2.4 of IEEE.C57.12.90–2015 and section 8.2.5 of IEEE C57.12.91–2020 provide the same for no-load loss measurement. These documents reflect current industry practices and manufacturers are already measuring losses at the transformer terminals. Therefore, DOE proposed to specify in section 4.3(c) of appendix A that both load loss and no-load loss measurements must be made from terminal to terminal. 84 FR 20704, 20719.

DOE received no comments in response to this proposal and is adopting it in this final rule.

4. Specification for Stabilization of Current and Voltage

Section 3.3.2 and 3.3.1 of appendix A describe a voltmeter-ammeter method and resistance bridge methods, respectively, for measuring resistance. Both methods require measurements to be stable before determining the resistance of the transformer winding being measured. Specifically, the voltmeter-ammeter method in section 3.3.2(b) of appendix A requires that current and voltage readings be stable before taking simultaneous readings of current and voltage to determine winding resistance. For the resistance bridge methods, section 3.3.1 of appendix A requires the bridge to be balanced (*i.e.,* no voltage across it or current through it) before determining winding resistance. Both methods allow for a resistor to reduce the time constant of the circuit, but do not explicitly specify how to determine when measurements are stable. DOE notes that IEEE C57.12.90–2015, IEEE C57.12.91–2020, IEEE C57.12.00–2015, and IEEE C57.12.01–2020 do not specify how to determine that stabilization is reached. Section 3.4.2 of appendix A provides related instruction for improving measurement accuracy of resistance by reducing the transformer's time constant. However, section 3.4.2 also does not explicitly provide for the period of time (such as a certain multiple of the time constant) necessary to achieve stability. In the May 2019 NOPR, DOE requested comment on how industry currently determines that measurements have stabilized before determining winding resistance using both voltmeter-ammeter method and resistance bridge methods. 84 FR 20704, 20719.

NEMA commented that testing is typically done with a computer/electronic automatic test system where the feature is provided. NEMA stated that its members have not used a resistance bridge method in 20 years. (NEMA, No. 30 at p. 4) HVOLT and CDA commented that both the resistance bridge and voltmeter-ammeter methods should be accurate as long as four-time constants have passed. (HVOLT, No. 27 at p. 93; CDA, No. 29 at p. 3)

Commenters have not suggested that there is an issue with the accuracy of measurements associated with achieving sufficient stability and did not suggest that DOE needed to explicitly provide for the period of time necessary to achieve stability. Therefore, DOE has not adopted any amendments related to the period of time to achieve stability.

5. Ambient Temperature Tolerances

In response to the September 2017 RFI, NEMA recommended that DOE increase the ambient temperature tolerances for testing dry-type transformers, stating that testing may otherwise be burdensome in laboratories that are not climate controlled, and that a mathematical correction factor could be developed as an alternative to the temperature limits. (NEMA, Docket No. EERE–2017–BT–0055–0014 at p. 2)

In the May 2019 NOPR, DOE explained that while widening the tolerances of temperatures (or other measured parameters) may reduce testing cost, it may impact the reproducibility and repeatability of the test result. 84 FR 20704, 20719–20720. Further, NEMA acknowledged that manufacturers are not having difficulty meeting the temperature requirement. (NEMA, Docket No. EERE–2017–BT–0055–0014 at p. 8)

DOE does not have data regarding typical ranges of laboratory ambient temperature and, as a result, cannot be certain that reduction in temperature tolerance would not impact reproducibility, repeatability, and accuracy and cause future test results to become incomparable to past data. For these reasons, DOE did not propose amendments to the laboratory ambient temperature and transformer internal temperature requirements in the May 2019 NOPR. 84 FR 20704, 20720.

Comments received on this issue supported maintaining the current ambient temperature tolerances. (Howard, No. 31 at p. 1; NEMA, No. 30 at p. 4; CDA, No. 29 at p. 3; HVOLT, No. 27 at p. 93) For the reasons discussed in the May 2019 NOPR and in the preceding paragraph, DOE is maintaining the ambient temperature requirements in appendix A.

6. Harmonic Current

Harmonic current refers to electrical power at alternating current frequencies greater than the fundamental frequency. Distribution transformers in service are commonly subject to (and must tolerate) harmonic current of a degree that varies by application. Sections 4.4.1(a) and 4.4.3.2(a) of appendix A direct use of a sinusoidal waveform for evaluating efficiency in distribution transformers.

DOE recognizes that transformers in service are subject to a variety of harmonic conditions, and that the test procedure must provide a common basis for comparison. Currently, the test procedure states that transformers designed for harmonic currents must be tested with a sinusoidal waveform (*i.e.,* free of harmonic current), but does not do so for all other varieties of transformers. However, the intent of the test procedure is for all transformers to be tested with a sinusoidal waveform, as is implicit in section 4.4.1(a) of appendix A. To clarify this test setup requirement, DOE proposed to modify section 4.1 of appendix A to read ''. . . Test all distribution transformers using a sinusoidal waveform (k=1).'' 84 FR 20704, 20720 This is consistent with industry practice and manufacturers are already testing all distribution transformers using a sinusoidal waveform. *Id.*

DOE received several comments in support of this clarification and none in opposition. (Howard, No. 32 at p. 2; NEMA, No. 30 at p. 4; CDA, No. 29 at p. 3; HVOLT, No. 27 at p. 93) For the reasons discussed in the May 2019 NOPR and in the preceding paragraph, DOE is adopting the clarification regarding use of a sinusoidal waveform as proposed.

7. Other Editorial Revisions

In the May 2019 NOPR, DOE proposed the following editorial updates to improve the readability of the test procedure and provide additional detail: (i) Revising ''shall'' (and a single instance of ''should'' in the temperature condition requirements at section 3.2.2(b)(3)) to ''must'' throughout appendix A, (ii) clarifying the instructional language for recording the winding temperature for dry-type transformers (section 3.2.2 of appendix A), (iii) separating certain sentences into enumerated clauses (section 3.2.2(a) of appendix A),[30] (iv) identifying the corresponding resistance measurement method sections (section 3.3 of appendix A), (v) replacing a reference to ''uniform test method'' with ''this appendix'' (section 3.3 of appendix A), (vi) removing reference to guidelines under section 3.4.1, *Required actions,* of appendix A to clarify that section establishes requirements, (vii) specifying the maximum amount of time for the temperature of the transformer windings to stabilize (section 3.2.2(b)(4) of appendix A [31]), (viii) removing references to the test procedure in 10 CFR 431.196, and (ix) replacing any reference to accuracy requirements in ''section 2.0'' and/or ''Table 2.0'' to ''section 2.3'' and/or ''Table 2.3,'' accordingly. 84 FR 20704, 20720.

Section 3.2.2 of appendix A requires that, for testing of both ventilated and sealed units, the ambient temperature of the test area may be used to estimate the winding temperature (rather than direct measurement of the winding temperature), provided a number of conditions are met, including the condition that neither voltage nor current has been applied to the unit under test for 24 hours (provided in section 3.2.2(b)(4) of appendix A). The same section also allows for the time period of the initial 24 hours to be increased to up to a maximum of an additional 24 hours, so as to allow the temperature of the transformer windings to stabilize at the level of the ambient temperature. Based on this requirement, the total amount of time allowed would be a maximum of 48 hours. As such, in the May 2019 NOPR, DOE proposed to specify explicitly that, for section 3.2.2(b)(4) of appendix A, the total maximum amount of time allowed is 48 hours. *Id.*

DOE also proposed conforming amendments to the energy conservation standard provisions. The provisions in 10 CFR 431.196 establishes energy conservation standards for certain distribution transformers. *Id.* Immediately following each table of standards, a note specifies the applicable standard PUL and DOE test procedure. For example, in 10 CFR 431.196(a) the note reads, ''Note: All efficiency values are at 35 percent of nameplate-rated load, determined according to the DOE Test Method for Measuring the Energy Consumption of Distribution Transformers under appendix A to subpart K of 10 CFR part 431.'' Because 10 CFR 431.193 already requires that testing be in accordance with appendix A, DOE proposes to remove the references to the test procedure in 10 CFR 431.196. DOE proposes to maintain the portion of the note identifying the PUL corresponding to the efficiency values, for continuity and clarity. *Id.*

As discussed in sections III.F.1 and III.F.2 of this final rule, DOE is clarifying the PUL and reference temperature specifications for certification to energy conservation standards, and providing PUL and reference temperature specifications for voluntary representations, with a new section 2.1 for PUL requirements and section 2.2 for reference temperature requirements in appendix A. Accordingly, DOE proposed that the accuracy requirements previously provided in section 2.0 be moved to section 2.3 in appendix A. In addition, DOE proposed to re-number Table 2.1, Test System Accuracy Requirements for Each Measured Quantity, to Table 2.3. Lastly, DOE proposed to update cross-

[30] Under the changes adopted in this document, section 3.2.2(a) of appendix A is split into section 3.2.2(a) and section 3.2.2(b).

[31] Under the changes adopted in this document, this section is redesignated as section 3.2.2(c)(4) of appendix A.

references in appendix A to the accuracy requirements in section 2.0 and/or Table 2.1, to section 2.3 and/or Table 2.3. The cross-references occur in sections 3.1(b), 3.3.3, 3.4.2(a), 4.3(a), 6.0, and 6.2 of appendix A.

DOE did not receive any comment in opposition to these edits and is adopting them in the test procedure.

NEMA noted certain errors in the equation references in section 4 of appendix A. (NEMA, No. 30 at p. 5) Specifically, NEMA stated that the load loss power (P_{lc1}) appears with subscripts ''LCL'', ''LCI'', and ''LC1'' (capital letters used for clarity, but lower case used in the text). *Id.* DOE has reviewed the subscripts in section 4 of appendix A and corrected each instance to ''LC1'' (capitalized here for clarity) where necessary.

NEMA also noted that there is potential confusion regarding which reference temperature should be used in section 4.5.3.3 of appendix A. NEMA suggested to clarify the text as follows: ''When the measurement of load loss is made at a temperature T_{im} that is different from the reference temperature, use the procedure summarized in the equations 4–6 to 4–10 to correct the measured load loss to the reference temperature (as defined in 3.5 (a)).'' (NEMA, No. 30 at p. 5–6) This final rule includes a new section, section 2.2 of appendix A, to specify reference temperature in a centralized location, as described in section III.F.2 of this document. In view of the new requirement, NEMA's suggested edits to specify reference temperature in section 4.5.3.3 are redundant.

PG&E commented in response to the May 2019 NOPR that in order to properly comment, it would like a before and after document of proposed changes to the CFR. (PG&E, No. 33 at p. 1) The May 2019 NOPR includes a synopsis table of the proposed changes, including a side-by-side comparison of the current DOE TP language, the proposed test procedure language, and attribution of the changes. 84 FR 20704, 20706. Further, DOE published all proposed regulatory text in the May 2019 NOPR which could be juxtaposed with the current CFR in order to perform the comparison PG&E describes. 84 FR 20704, 20727–20730.

G. Effective and Compliance Dates

The effective date for the adopted test procedure amendment is 30 days after publication of this final rule in the **Federal Register**. EPCA prescribes that all representations of energy efficiency and energy use, including those made on marketing materials and product labels, must be made in accordance with an amended test procedure, beginning 180 days after publication of the final rule in the **Federal Register**. (42 U.S.C. 6293(c)(2); 42 U.S.C. 6314(d)(1)) EPCA provides an allowance for individual manufacturers to petition DOE for an extension of the 180-day period if the manufacturer may experience undue hardship in meeting the deadline. (42 U.S.C. 6293(c)(3); 42 U.S.C. 6314(d)(2)) To receive such an extension, petitions must be filed with DOE no later than 60 days before the end of the 180-day period and must detail how the manufacturer will experience undue hardship. (*Id.*)

H. Test Procedure Costs

In this final rule, DOE is amending the existing test procedure for distribution transformers by revising certain definitions, incorporating new definitions, incorporating revisions based on the latest versions of the IEEE industry testing standards, including provisions to allow manufacturers to use the DOE test procedure to make voluntary representations at additional PULs and/or reference temperatures, and reorganizing content among relevant sections of the CFR to improve readability. The adopted amendments primarily provide updates and supplemental details for how to conduct the test procedure and do not add complexity to test conditions/setup or add test steps. In accordance with EPCA, DOE has determined that these adopted amendments will not be unduly burdensome for manufacturers to conduct. Further, DOE has determined that the adopted test procedure amendments will not impact testing costs already experienced by manufacturers. DOE estimated, based on a test quote from a laboratory, that the cost for testing distribution transformers using the existing test procedure is approximately $400 per unit tested and that this figure will not change in response to the adopted test procedure amendments. In summary, the adopted test procedure amendments reflect and codify current industry practice.

As previously described in the May 2019 NOPR, the adopted amendments will not impact the scope of the test procedure. The adopted amendments will not require the testing of distribution transformers not already subject to the test procedure at 10 CFR 431.193 (*i.e.,* the adopted amendments will not require manufacturers to test autotransformers, drive (isolation) transformers, grounding transformers, machine-tool (control) transformers, nonventilated transformers, rectifier transformers, regulating transformers, sealed transformer; special-impedance transformer; testing transformer; transformer with tap range of 20 percent or more; uninterruptible power supply transformer; or welding transformer, which are presently not subject to testing). The adopted amendments will not alter the measured energy efficiency or energy use of the distribution transformers. Manufacturers will be able to rely on data generated under the current test procedure. Further, the adopted amendments will not require the purchase of additional equipment for testing.

In the May 2019 NOPR, DOE described why the proposed test procedure amendments would not add costs to manufacturers. In response, manufacturers commented stating the proposed testing should not increase testing costs for any manufacturers. (Howard, No. 32 at p. 2; CDA, No. 29 at p. 3–4; HVOLT, No. 27 at p. 91–93) NEMA commented that it does not anticipate any negative impact or increased costs associated with any of the proposed changes but stressed that DOE continue to allow manufacturers to certify distribution transformers using an AEDM as is allowed at 10 CFR 429.70(d) in order to minimize testing costs. (NEMA, No. 30 at p. 4) DOE notes that it has not proposed or adopted any changes to 10 CFR 429.70(d), and manufacturers are permitted to use an AEDM for means of certifying distribution transformer efficiency to DOE.

IV. Procedural Issues and Regulatory Review

A. Review Under Executive Order 12866

The Office of Management and Budget (''OMB'') has determined this test procedure rulemaking does not constitute a ''significant regulatory action'' under section 3(f) of Executive Order (''E.O.'') 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 final regulatory flexibility analysis (''FRFA'') for any final rule where the agency was first required by law to publish a proposed rule 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: *https://energy.gov/gc/office-general-counsel.*

As stated, the amendments adopted in this final rule revise certain definitions, incorporate new definitions, incorporate revisions based on the latest versions of the IEEE industry testing standards, include provisions to allow manufacturers to use the DOE test procedure to make voluntary representations at additional PULs and/or reference temperatures, and reorganize content among relevant sections of the CFR to improve readability. DOE has determined that the adopted test procedure amendments would not impact testing costs already experienced by manufacturers. NEMA, CDA, and HVOLT commented that they do not anticipate any undue burden on small businesses or small manufacturers. (NEMA, No. 30 at p. 5; CDA, No. 29 at p. 4; HVOLT, No. 27 at p. 94)

Therefore, DOE concludes that the cost effects accruing from the final rule would not have a "significant economic impact on a substantial number of small entities," and that the preparation of a FRFA is not warranted. DOE has submitted a 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

Manufacturers of distribution transformers must certify to DOE that their products comply with any applicable energy conservation standards. To certify compliance, manufacturers must first obtain test data for their products according to the DOE test procedure, including any amendments adopted for that test procedure. DOE has established regulations for the certification and recordkeeping requirements for all covered consumer products and commercial equipment, including distribution transformers. (See generally 10 CFR part 429.) The collection-of-information requirement for the certification and recordkeeping is subject to review and approval by OMB under the Paperwork Reduction Act (PRA). This requirement has been approved by OMB under OMB control number 1910–1400. Public reporting burden for the certification is estimated to average 35 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

The amendments adopted in this final rule do not impact the certification and reporting requirements for distribution transformers.

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

Pursuant to the National Environmental Policy Act of 1969 ("NEPA"), DOE has analyzed this action in accordance with NEPA and DOE's NEPA implementing regulations (10 CFR part 1021). DOE has determined that this rule qualifies for categorical exclusion under 10 CFR part 1021, subpart D, appendix A5, because it is an interpretive rulemaking that does not change the environmental effect of the rule and meets the requirements for application of a CX. *See* 10 CFR 1021.410. Therefore, DOE has determined that promulgation of this rule is not a major Federal action significantly affecting the quality of the human environment within the meaning of NEPA and does not require an EA or EIS.

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. Public Law 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 *https://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). Pursuant to OMB Memorandum M–19–15, Improving Implementation of the Information Quality Act (April 24, 2019), DOE published updated guidelines which are available at *www.energy.gov/sites/prod/files/2019/12/f70/DOE%20Final%20Updated%20IQA%20Guidelines%20Dec%202019.pdf.* 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 testing standards on competition.

The modifications to the test procedure for distribution transformers adopted in this final rule do not incorporate testing methods contained in commercial standards. Therefore, the requirements of section 32(b) of the FEAA do not apply.

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).

V. Approval of the Office of the Secretary

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

List of Subjects in 10 CFR Part 431

Administrative practice and procedure, Confidential business information, Energy conservation test procedures, and Reporting and recordkeeping requirements.

Signing Authority

This document of the Department of Energy was signed on September 2, 2021, by Kelly Speakes-Backman, Principal Deputy Assistant Secretary and Acting Assistant Secretary for Energy Efficiency and Renewable Energy, pursuant to delegated authority from the Secretary of Energy. That document with the original signature and date is maintained by DOE. For administrative purposes only, and in compliance with requirements of the

Office of the Federal Register, the undersigned DOE Federal Register Liaison Officer has been authorized to sign and submit the document in electronic format for publication, as an official document of the Department of Energy. This administrative process in no way alters the legal effect of this document upon publication in the **Federal Register**.

Signed in Washington, DC, on September 2, 2021.

Treena V. Garrett,

Federal Register Liaison Officer, U.S. Department of Energy.

For the reasons stated in the preamble, DOE amends part 431 of chapter II of title 10, Code of Federal Regulations as set forth below:

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

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

Authority: 42 U.S.C. 6291–6317; 28 U.S.C. 2461 note.

■ 2. Section 431.192 is amended by:
■ a. Adding in alphabetical order the definition for *Auxiliary device;*
■ b. Revising the definition of *Low-voltage dry-type distribution transformer;*
■ c. Adding in alphabetical order the definition for *Per-unit load;*
■ d. Revising the definition of *Reference temperature;* and
■ e. Adding in alphabetical order the definition for *Terminal.*

The additions and revisions read as follows:

§ 431.192 Definitions.

* * * * *

Auxiliary device means a localized component of a distribution transformer that is a circuit breaker, switch, fuse, or surge/lightning arrester.

* * * * *

Low-voltage dry-type distribution transformer means a distribution transformer that has an input voltage of 600 volts or less and has the core and coil assembly immersed in a gaseous or dry-compound insulating medium.

* * * * *

Per-unit load means the fraction of rated load.

* * * * *

Reference temperature means the temperature at which the transformer losses are determined, and to which such losses are corrected if testing is done at a different point. (Reference temperature values are specified in the test method in appendix A to this subpart.)

* * * * *

Terminal means a conducting element of a distribution transformer providing electrical connection to an external conductor that is not part of the transformer.

* * * * *

■ 3. Section 431.193 is revised to read as follows:

§ 431.193 Test procedure for measuring energy consumption of distribution transformers.

The test procedure for measuring the energy efficiency of distribution transformers for purposes of EPCA is specified in appendix A to this subpart. The test procedure specified in appendix A to this subpart applies only to distribution transformers subject to energy conservation standards at § 431.196.

■ 4. Section 431.196 is amended by revising the Notes in paragraphs (a)(1) and (2), (b)(1) and (2), and (c)(1) and (2) to read as follows:

§ 431.196 Energy conservation standards and their effective dates.

(a) * * *
(1) * * *

Note 1 to paragraph (a)(1): All efficiency values are at 35 percent per-unit load.

(2) * * *

Note 2 to paragraph (a)(2): All efficiency values are at 35 percent per-unit load.

(b) * * *
(1) * * *

Note 3 to paragraph (b)(1): All efficiency values are at 50 percent per-unit load.

(2) * * *

Note 4 to paragraph (b)(2): All efficiency values are at 50 percent per-unit load.

(c) * * *
(1) * * *

Note 5 to paragraph (c)(1): All efficiency values are at 50 percent per-unit load.

(2) * * *

Note 6 to paragraph (c)(2): All efficiency values are at 50 percent per-unit load.

* * * * *

■ 5. Appendix A to subpart K of part 431 is amended by:
■ a. In section 2.0:
■ i. Revising the section heading;
■ ii. Removing paragraphs (a) and (b); and
■ iii. Adding sections 2.1, 2.2, and 2.3;
■ b. Adding paragraph (c) to section 3.1;
■ c. Revising section 3.2.1.1;
■ d. Revising paragraph (b) in section 3.2.1.2;
■ e. Revising section 3.2.2;
■ f. Revising section 3.3;
■ g. Revising paragraph (a) introductory text and paragraph (b) in section 3.3.2;
■ h. Revising section 3.3.3;
■ i. Revising the introductory text and adding paragraphs (f), (g), (h), and (i) in section 3.4.1;
■ j. Revising paragraph (a) in section 3.4.2;
■ k. Revising paragraph (a) in section 3.5;
■ l. Revising section 4.1;
■ m. Revising paragraph (a) and adding paragraph (c) in section 4.3;
■ n. Revising section 4.4.3.3;
■ o. Revising paragraph (c) of section 4.5.3.2;
■ p. Revising section 5.1;
■ q. Revising section 6.0;
■ r. Revising section 6.1;
■ s. Revising paragraph (a) in section 6.2; and
■ t. Adding section 7.0.

The additions and revisions read as follows:

Appendix A to Subpart K of Part 431—Uniform Test Method for Measuring the Energy Consumption of Distribution Transformers

* * * * *

2.0 Per-Unit Load, Reference Temperature, and Accuracy Requirements

2.1 Per-Unit Load

In conducting the test procedure in this appendix for the purpose of:
(a) Certification to an energy conservation standard, the applicable per-unit load in Table 2.1 must be used; or
(b) Making voluntary representations as provided in section 7.0 at an additional per-unit load, select the per-unit load of interest.

TABLE 2.1—PER-UNIT LOAD FOR CERTIFICATION TO ENERGY CONSERVATION STANDARDS

Distribution transformer category	Per-unit load (percent)
Liquid-immersed	50
Medium-voltage dry-type	50
Low-voltage dry-type	35

2.2 Reference Temperature

In conducting the test procedure in this appendix for the purpose of:
(a) Certification to an energy conservation standard, the applicable reference temperature in Table 2.2 must be used; or
(b) Making voluntary representations as provided in section 7.0 at an additional reference temperature, select the reference temperature of interest.

TABLE 2.2—REFERENCE TEMPERATURE FOR CERTIFICATION TO ENERGY CONSERVATION STANDARDS

Distribution transformer category	Reference temperature
Liquid-immersed	20 °C for no-load loss. 55 °C for load loss.
Medium-voltage dry-type	20 °C for no-load loss. 75 °C for load loss.
Low-voltage dry-type	20 °C for no-load loss. 75 °C for load loss.

2.3 Accuracy Requirements

(a) Equipment and methods for loss measurement must be sufficiently accurate that measurement error will be limited to the values shown in Table 2.3.

TABLE 2.3—TEST SYSTEM ACCURACY REQUIREMENTS FOR EACH MEASURED QUANTITY

Measured quantity	Test system accuracy
Power Losses	±3.0%.
Voltage	±0.5%.
Current	±0.5%.
Resistance	±0.5%.
Temperature	±1.5 °C for liquid-immersed distribution transformers, and ±2.0 °C for low-voltage dry-type and medium-voltage dry-type distribution transformers.

(b) Only instrument transformers meeting the 0.3 metering accuracy class, or better, may be used under this test method.

3.0 * * *

3.1 General Considerations

* * * * *

(c) Measure the direct current resistance (R_{dc}) of transformer windings by one of the methods outlined in section 3.3. The methods of section 3.5 must be used to correct load losses to the applicable reference temperature from the temperature at which they are measured. Observe precautions while taking measurements, such as those in section 3.4, in order to maintain measurement uncertainty limits specified in Table 2.3 of this appendix.

* * * * *

3.2.1.1 Methods

Record the winding temperature (T_{dc}) of liquid-immersed transformers as the average of either of the following:

(a) The measurements from two temperature sensing devices (for example, thermocouples) applied to the outside of the transformer tank and thermally insulated from the surrounding environment, with one located at the level of the insulating liquid and the other located near the tank bottom or at the lower radiator header if applicable; or

(b) The measurements from two temperature sensing devices immersed in the insulating liquid, with one located directly above the winding and other located directly below the winding.

3.2.1.2 Conditions

* * * * *

(b) The temperature of the insulating liquid has stabilized, and the difference between the top and bottom temperature does not exceed 5 °C. The temperature of the insulating liquid is considered stable if the top liquid temperature does not vary more than 2 °C in a 1-h period.

3.2.2 Dry-Type Distribution Transformers

Record the winding temperature (T_{dc}) of dry-type transformers as one of the following:

(a) For ventilated dry-type units, use the average of readings of four or more thermometers, thermocouples, or other suitable temperature sensors inserted within the coils. Place the sensing points of the measuring devices as close as possible to the winding conductors; or

(b) For sealed units, such as epoxy-coated or epoxy-encapsulated units, use the average of four or more temperature sensors located on the enclosure and/or cover, as close to different parts of the winding assemblies as possible; or

(c) For ventilated units or sealed units, use the ambient temperature of the test area, only if the following conditions are met:

(1) All internal temperatures measured by the internal temperature sensors must not differ from the test area ambient temperature by more than 2 °C. Enclosure surface temperatures for sealed units must not differ from the test area ambient temperature by more than 2 °C.

(2) Test area ambient temperature must not have changed by more than 3 °C for 3 hours before the test.

(3) Neither voltage nor current has been applied to the unit under test for 24 hours. In addition, increase this initial 24-hour period by any added amount of time necessary for the temperature of the transformer windings to stabilize at the level of the ambient temperature. However, this additional amount of time need not exceed 24 hours (*i.e.,* after 48 hours, the transformer windings can be assumed to have stabilized at the level of the ambient temperature. Any stabilization time beyond 48 hours is optional).

3.3 Resistance Measurement Methods

Make resistance measurements using either the resistance bridge method (section 3.3.1), the voltmeter-ammeter method (section 3.3.2) or resistance meters (section 3.3.3). In each instance when this appendix is used to test more than one unit of a basic model to determine the efficiency of that basic model, the resistance of the units being tested may be determined from making resistance measurements on only one of the units.

* * * * *

3.3.2 Voltmeter-Ammeter Method

(a) Employ the voltmeter-ammeter method only if the test current is limited to 15 percent of the winding current. Connect the transformer winding under test to the circuit shown in Figure 3.3 of this appendix.

* * * * *

(b) To perform the measurement, turn on the source to produce current no larger than 15 percent of the rated current for the winding. Wait until the current and voltage readings have stabilized and then take a minimum of four readings of voltage and current. Voltage and current readings must be taken simultaneously for each of the readings. Calculate the average voltage and average current using the readings. Determine the winding resistance R_{dc} by using equation 3–4 as follows:

$$R_{dc} = (V_{mdc}/I_{mdc}) \qquad (3\text{-}4)$$

Where:

V_{mdc} is the average voltage measured by the voltmeter V; and

I_{mdc} is the average current measured by the ammeter (A).

* * * * *

3.3.3 Resistance Meters

Resistance meters may be based on voltmeter-ammeter, or resistance bridge, or some other operating principle. Any meter used to measure a transformer's winding resistance must have specifications for resistance range, current range, and ability to measure highly inductive resistors that cover the characteristics of the transformer being tested. Also, the meter's specifications for accuracy must meet the applicable criteria of Table 2.3 in section 2.3 of this appendix.

* * * * *

3.4.1 Required Actions

The following requirements must be observed when making resistance measurements:

* * * * *

(f) Keep the polarity of the core magnetization constant during all resistance measurements.

(g) For single-phase windings, measure the resistance from terminal to terminal. The total winding resistance is the terminal-to-terminal measurement. For series-parallel windings, the total winding resistance is the sum of the series terminal-to-terminal section measurements.

(h) For wye windings, measure the resistance from terminal to terminal or from terminal to neutral. For the total winding resistance, the resistance of the lead from the neutral connection to the neutral bushing may be excluded. For terminal-to-terminal measurements, the total resistance reported is the sum of the three measurements divided by two.

(i) For delta windings, measure resistance from terminal to terminal with the delta closed or from terminal to terminal with the delta open to obtain the individual phase readings. The total winding resistance is the sum of the three-phase readings if the delta is open. If the delta is closed, the total winding resistance is the sum of the three phase-to-phase readings times 1.5.

3.4.2 Guideline for Time Constant

(a) The following guideline is suggested for the tester as a means to facilitate the measurement of resistance in accordance with the accuracy requirements of section 2.3:

* * * * *

3.5 Conversion of Resistance Measurements

(a) Resistance measurements must be corrected from the temperature at which the winding resistance measurements were made, to the reference temperature.

* * * * *

4.0 * * *

4.1 General Considerations

The efficiency of a transformer is computed from the total transformer losses, which are determined from the measured value of the no-load loss and load loss power components. Each of these two power loss components is measured separately using test sets that are identical, except that shorting straps are added for the load-loss test. The measured quantities need correction for instrumentation losses and may need corrections for known phase angle errors in measuring equipment and for the waveform distortion in the test voltage. Any power loss not measured at the applicable reference temperature must be adjusted to that reference temperature. The measured load loss must also be adjusted to a specified output loading level if not measured at the specified output loading level. Test all distribution transformers using a sinusoidal waveform (k = 1). Measure losses with the transformer energized by a 60 Hz supply.

* * * * *

4.3 Test Sets

(a) The same test set may be used for both the no-load loss and load loss measurements provided the range of the test set encompasses the test requirements of both tests. Calibrate the test set to national standards to meet the tolerances in Table 2.3 in section 2.3 of this appendix. In addition, the wattmeter, current measuring system and voltage measuring system must be calibrated separately if the overall test set calibration is outside the tolerance as specified in section 2.3 or the individual phase angle error exceeds the values specified in section 4.5.3.

* * * * *

(c) Both load loss and no-load loss measurements must be made from terminal to terminal.

* * * * *

4.4.3.3 Correction of No-Load Loss to Reference Temperature

After correcting the measured no-load loss for waveform distortion, correct the loss to the reference temperature. For both certification to energy conservation standards and voluntary representations, if the correction to reference temperature is applied, then the core temperature of the transformer during no-load loss measurement (T_{nm}) must be determined within ±10 °C of the true average core temperature. For certification to energy conservation standards only, if the no-load loss measurements were made between 10 °C and 30 °C, this correction is not required. Correct the no-load loss to the reference temperature by using equation 4–2 as follows:

$$P_{nc} = P_{nc1}[1 + 0.00065(T_{nm} - T_{nr})] \qquad (4\text{-}2)$$

Where:

P_{nc} is the no-load losses corrected for waveform distortion and then to the reference temperature;
P_{nc1} is the no-load losses, corrected for waveform distortion, at temperature T_{nm};
T_{nm} is the core temperature during the measurement of no-load losses; and
T_{nr} is the reference temperature.

* * * * *

4.5.3.2 Correction for Phase Angle Errors

* * * * *

(c) If the correction for phase angle errors is to be applied, first examine the total system phase angle ($\beta_w - \beta_v + \beta_c$). Where the total system phase angle is equal to or less than ±12 milliradians (±41 minutes), use either equation 4–4 or 4–5 to correct the measured load loss power for phase angle errors, and where the total system phase angle exceeds ±12 milliradians (±41 minutes) use equation 4–5, as follows:

$$P_{lc1} = P_{lm} - V_{lm}I_{lm}(\beta_w - \beta_v + \beta_c)\sin\varphi \qquad (4\text{-}4)$$

$$P_{lc1} = V_{lm}I_{lm}\cos(\varphi + \beta_w - \beta_v + \beta_c) \qquad (4\text{-}5)$$

* * * * *

5.0 * * *

5.1 Output Loading Level Adjustment

If the per-unit load selected in section 2.1 is different from the per-unit load at which the load loss power measurements were made, then adjust the corrected load loss power, P_{lc2}, by using equation 5–1 as follows:

$$P_{lc} = P_{lc2}\left[\frac{P_{os}}{P_{or}}\right]^2 = P_{lc2}L^2 \qquad (5\text{-}1)$$

Where:

P_{lc} is the adjusted load loss power to the per-unit load;
P_{lc2} is as calculated in section 4.5.3.3;
P_{or} is the rated transformer apparent power (name plate);
P_{os} is the adjusted rated transformer apparent power, where $P_{os} = P_{or}L$; and
L is the per-unit load, *e.g.,* if the per-unit load is 50 percent then ''L'' is 0.5.

* * * * *

6.0 Test Equipment Calibration and Certification

Maintain and calibrate test equipment and measuring instruments, maintain calibration records, and perform other test and measurement quality assurance procedures according to the following sections. The calibration of the test set must confirm the accuracy of the test set to that specified in section 2.3, Table 2.3 of this appendix.

6.1 Test Equipment

The party performing the tests must control, calibrate, and maintain measuring and test equipment, whether or not it owns the equipment, has the equipment on loan, or the equipment is provided by another party. Equipment must be used in a manner which assures that measurement uncertainty is known and is consistent with the required measurement capability.

6.2 Calibration and Certification

* * * * *

(a) Identify the measurements to be made, the accuracy required (section 2.3) and select the appropriate measurement and test equipment;

* * * * *

7.0 Test Procedure for Voluntary Representations

Follow sections 1.0 through 6.0 of this appendix using the per-unit load and/or reference temperature of interest for voluntary representations of efficiency, and corresponding values of load loss and no-load loss at additional per-unit load and/or reference temperature. Representations made at a per-unit load and/or reference temperature other than those required to comply with the energy conservation standards at § 431.196 must be in addition to, and not in place of, a representation at the required DOE settings for per-unit load and reference temperature. As a best practice, the additional settings of per-unit load and reference temperature should be provided with the voluntary representations.

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