ENERGY STAR® Product Specification for Distribution Transformers

Eligibility Criteria Final Draft Version 1.0

Following is the Version 1.0 ENERGY STAR product specification for Distribution Transformers. A product shall meet all of the identified criteria if it is to earn ENERGY STAR recognition.

1 DEFINITIONS[1]

A) Product Classifications:

1. Transformer: A device consisting of 2 or more coils of insulated conductor that transfers alternating current by electromagnetic induction from 1 coil to another to change the original voltage or current value.

> **Note:** EPA has modified the definition of Transformer to mention "insulated conductor" instead of "insulated wire" to reflect different technologies available for conductor choice.

2. Distribution Transformer: A transformer that:
   a) Has an input voltage of 34.5 kV or less;
   b) Has an output voltage of 600 V or less;
   c) Is rated for operation at a frequency of 60 Hz; and
   d) Has a capacity of 10 kVA to 2500 kVA for liquid-immersed units and 15 kVA to 2500 kVA for dry-type units.
   e) The term “distribution transformer” does not include a transformer that is a(n)—
      i. Autotransformer;
      ii. Drive (isolation) transformer;
      iii. Grounding transformer;
      iv. Machine-tool (control) transformer;
      v. Nonventilated transformer;
      vi. Rectifier transformer;
      vii. Regulating transformer;
      viii. Sealed transformer;
      ix. Special-impedance transformer;
      x. Testing transformer;
      xi. Transformer with tap range of 20 percent or more;
      xii. Uninterruptible power supply transformer; or

[1] Definitions are based on the U.S. Department Of Energy, "Energy Conservation Program for Certain Commercial and Industrial Equipment: Distribution Transformers: Definitions", 10 CFR 431.192.

xiii. Welding transformer.

B) <u>Product Types</u>:

1. <u>Liquid-immersed Distribution Transformers</u>: A distribution transformer in which the core and coil assembly is immersed in an insulating liquid.

2. <u>Low-voltage Dry-Type Distribution Transformer</u>: A distribution transformer that:

    a) Has an input voltage of 600 volts or less;

    b) Is air-cooled; and

    c) Does not use oil as a coolant.

3. <u>Medium-voltage Dry-type Distribution Transformer</u>: 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.

C) <u>Operational Power States</u>:

1. <u>No-Load Loss (or Core Loss)</u>: Losses that are incident to the excitation of the transformer at rated voltage.

2. <u>Load Loss (or Coil Loss)</u>: Losses that are incident to a specified load carried by the transformer, including losses in the windings as well as stray losses in the conducting parts of the transformer.

3. <u>Total Loss</u>: The sum of the no-load loss and load loss for a transformer.

Note: EPA has modified the definition of No-Load Loss to include "at rated voltage" for clarity.

D) <u>Basic Model</u>: A group of models of distribution transformers manufactured by a single manufacturer, that have the same insulation type (i.e., liquid-immersed), have the same number of phases (i.e., single or three), have the same standard kVA rating, and do not have any differentiating electrical, physical or functional features that affect energy consumption. Differences in voltage and differences in basic impulse insulation level (BIL) rating are examples of differentiating electrical features that affect energy consumption.

E) <u>Per Unit Load</u>: The ratio of the current through a transformer's output winding multiplied by the nameplate voltage and divided by the capacity, at unity power factor and zero input voltage distortion.

F) <u>Load Factor</u>: The ratio of the average load over a period of time to the peak load during that time.[2]

G) <u>Basic Impulse Level (BIL)</u>: Refers to the level of insulation wound into a transformer, dictating its design voltage[3].

Note: EPA has added a definition for Basic Impulse Level (BIL) to inform the scope exclusion of products with a BIL greater than 150 kV.

[2] IEEE PC57.120/D16.1 Loss Evaluation Guide for Distribution and Power Transformers and Reactors, March 2013, 18.
[3] U.S. Department Of Energy, "2012-02-03 Technical Support Document", https://www.regulations.gov/document?D=EERE-2010-BT-STD-0048-0104.

2 SCOPE

2.1 Included Products

2.1.1 Products that meet the definition of Liquid-Immersed Distribution Transformers are eligible for ENERGY STAR certification.

2.2 Excluded Products

2.2.1 Products that are covered under other ENERGY STAR product specifications are not eligible for certification under this specification. The list of specifications currently in effect can be found at www.energystar.gov/specifications.

2.2.2 The following products are not eligible for certification under this specification:

i. The following types of Liquid-Immersed Distribution Transformers:

(1) Single-phase with capacity greater than 500 kVA;

(2) Three-phase transformers intended for a vault application; and

(3) All transformers with a BIL > 150 kV.

ii. Low-voltage Dry-Type Distribution Transformer; and

iii. Medium-voltage Dry-type Distribution Transformer.

Note: EPA has excluded single-phase transformers larger than 500 kVA, three-phase vault transformers, and all transformers with a BIL greater than 150 kV due to a lack of data on appropriate efficiency criteria. In its call for data from stakeholders, EPA did not receive any data on products that would be able to meet efficiency criteria beyond the DOE specification. Since these types of transformers represent a low market share, excluding them will likely not significantly impact energy savings potential. EPA will continue to monitor the market to determine the feasibility of and energy savings opportunity for including these types of products within the scope of the specification in a future revision.

3 CERTIFICATION CRITERIA

3.1 Significant Digits and Rounding

3.1.1 All calculations shall be carried out with actual measured (unrounded) values. Only the final result of a calculation shall be rounded.

3.1.2 Unless otherwise specified, compliance with specification limits shall be evaluated using exact values without any benefit from rounding.

3.1.3 Directly measured or calculated values that are submitted for reporting on the ENERGY STAR website shall be rounded to the nearest significant digit as expressed in the corresponding specification limit.

3.2 Total Owning Cost

3.2.1 Manufacturers are encouraged to highlight for purchasers the total owning cost savings over the lifetime of the product, based on a utility's no-load and load loss evaluation factors. Manufacturers should calculate the total owning cost savings taking into account the utility's A (no-load) and B (load) loss evaluation factors and comparing them to that for the manufacturer's design that just complies with Federal standards.

i. TOC shall be calculated per Equation 1.[4]

Equation 1: Total Owning Cost

$$TOC = P + A \times NL + B \times LL_{85°C}$$

Where:

- *TOC is the Total Owning Cost;*
- *P is the bid price in dollars (USD);*
- *A is the utility's equivalent first cost of no-load losses, in dollars per watt;*
- *NL is the no-load loss power corrected for wave-form distortion and then to the reference temperature of 20°C, in watts;*
- *B is the utility's equivalent first cost of load losses, in dollars per watt; and*
- *$LL_{85°C}$ is the load loss power corrected to the reference temperature of 85°C and incorporating ohmic and stray losses, in watts.*

3.3 Energy Savings at Optimized Load Factor

3.3.1 The Percentage Energy Savings over the minimum DOE-compliant Design, calculated per Equation 2, shall be greater than or equal to the requirement specified in Table 1, subject to the following requirements.

i. A model meeting the requirements at one of the load factors can become ENERGY STAR certified for that specific load factor. The model will thus need to be marketed as certified only for use at the load factors where it meets the requirements in Table 1.

ii. For models with multiple ratings, each portion of the transformer shall meet the criteria applicable to the portion's kVA rating.

Note: EPA has issued a clarification to the specification that transformers with multiple ratings and duplex transformers shall have each portion of the unit meet the criteria applicable to the portion's kVA rating.

Equation 2: Percentage Energy Savings over Minimum DOE-compliant Design

$$Savings = \frac{(LL_{DOE} \times L^2 + NL_{DOE}) - (LL_{TOC} \times L^2 + NL_{TOC})}{LL_{DOE} \times L^2 + NL_{DOE}} \times 100\%$$

Where:

- *$Savings$ is the Percentage Energy Savings over the minimum DOE-compliant design at the utility-specified load factor;*
- $NL_{DOE} = \frac{kVA}{4} \times \frac{(1-Efficiency_{DOE})}{Efficiency_{DOE}} * 1000$, *where kVA is the capacity and, $Efficiency_{DOE}$ is the DOE minimum efficiency specified in 10 CFR 431.196(b)(2) as a decimal;*
- *$LL_{DOE} = 4 \times NL_{DOE}$*
- *L is the load factor at which the losses are evaluated, with 100% load factor equal to capacity.*

[4] IEEE PC57.120/D16.1 Loss Evaluation Guide for Distribution and Power Transformers and Reactors, October 2016, 5.

- LL_{TOC} *is the full load winding loss power of the TOC-optimized design corrected to the reference temperature of 55°C and incorporating ohmic and stray losses; and*
- NL_{TOC} *is the no-load loss power of the TOC-optimized design corrected for wave-form distortion and then to the reference temperature of 20°C.*

Note: EPA updated Equation 2 with the assumption that the minimum DOE designs will have a core loss equal to load loss at the 50% load factor. This approach will reduce burden for manufacturers by keeping the performance of the DOE model a constant for a given capacity for all manufacturers, rather than a variable that would need to be modeled for each TOC-optimized design.

Table 1: Minimum Percent Energy Saving at Operating Load Factors

Range of Utility Specified Load Factors:				< 30%	30–40%	> 40–55%	> 55%
Specific Load Factor at which Requirements Must be Met:				25%	35%	50%	65%
				↓	↓	↓	↓
Design Line	**Number of Phases**	**Tank Shape**	**Capacity Range (kVA)**	**Percentage Energy Savings over Minimum DOE-compliant Design (%)**			
1	1	Rectangular	≤ 167	25%	12%	11%	21%
2	1	Round	≤ 167	25%	12%	14%	25%
3	1	Round	> 167	25%	12%	20%	27%
4	3	Rectangular	≤ 500	25%	12%	19%	29%
5	3	Rectangular	> 500	25%	12%	16%	16%

Note: EPA has maintained the requirements for the load factor ranges that were presented in Draft 2, but divided the high load factor bin into two: > 40–55% and > 55% (in Draft 2, the highest bin included load factors > 40%). EPA made this modification based on stakeholder feedback requesting a specific load bin greater than 40% and subsequently found that having a higher load bin will also generate more energy savings.

In addition, EPA has provided energy savings requirements for Design Lines (DLs) 3 and 5 at the lower load factor bins. These were marked as TBD in the Draft 2 specification due to concerns with additional core weight required to meet the same requirements as the other design lines, especially for DL 3. EPA requested data from stakeholders but did not receive any. Instead, EPA performed its own analysis and found that meeting the requirements would increase weight by 11% if using M3 steel and not increase it at all if using DR80. Due to these modest increases, EPA is proposing the same requirements as for the other Design Lines.

Finally, EPA received feedback that optimizing transformers at each utility-provided load factor within a bin would be burdensome for manufacturers. To reduce burden, EPA has provided specific load factors in the midpoint of each bin at which the requirement shall be met. Based on analysis, EPA does not expect this to decrease savings significantly. The midpoint was chosen by reviewing the RMS load distribution for DL 1 previously developed by DOE. Designating one load factor within a bin should simplify the process of providing ENERGY STAR designs in response to a customer request. A manufacturer will be able to provide just a single ENERGY STAR design that is acceptable across the entire load factor bin, rather than ensuring that its designs meet the requirements each time a utility purchaser provides a load factor. For example, if a utility requests a transformer for a load factor of 39%, the manufacturer would only have to ensure that its proposed designs provide 12% savings over the minimum DOE compliant design at 35% rather than at 39%. This same design could also be provided to a subsequent request at 32% load factor.

4 TESTING

4.1 Test Methods

4.1.1 Test methods identified in Table 2 shall be used to determine certification for ENERGY STAR.

Table 2: Test Methods for ENERGY STAR Certification

Product Type	Test Method
All	U.S. Department of Energy, "Test procedures for measuring energy consumption of distribution transformers", Appendix A to Subpart K of 10 CFR Part 431

4.2 Number of Units Required for Testing

4.2.1 Basic Model shall be selected for testing per the requirements in the Department of Energy Certification Requirements for Distribution Transformers, 10 CFR 429.47.

i. For certification of an individual product model, the Basic Model shall be the model which is intended to be marketed and labeled as ENERGY STAR.

ii. For certification of multiple product models under the Basic Model definition, the Alternative Efficiency Determination Method (AEDM) may be used to certify all subsequent models that meet the Basic Model parameters.

Note: EPA will allow transformer manufacturers to follow the same laboratory testing procedures when certifying a product to ENERGY STAR as they do when reporting their product performance to DOE. As such, manufacturers will be able to use both the same actual test results submitted to DOE as well as modeled results from the same alternative efficiency determination method (AEDM) they currently use to demonstrate DOE compliance, allowing for more timely response to potential customers regarding ENERGY STAR status of design options.

5 EFFECTIVE DATE

5.1.1 Effective Date: The Version 1.0 ENERGY STAR Distribution Transformers specification shall take effect on **TBD**. To certify for ENERGY STAR, a product model shall meet the ENERGY STAR specification in effect on the model's date of manufacture. The date of manufacture is specific to each unit and is the date on which a unit is considered to be completely assembled.

5.1.2 Future Specification Revisions: EPA reserves the right to change this specification should technological and/or market changes affect its usefulness to consumers, industry, or the environment. In keeping with current policy, revisions to the specification are arrived at through stakeholder discussions. In the event of a specification revision, please note that the ENERGY STAR certification is not automatically granted for the life of a product model.