ENERGY STAR® Product Specification for Distribution Transformers

Eligibility Criteria
Draft 1 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 the ENERGY STAR.

1 DEFINITIONS[1]

A) Product Classifications:

1. Transformer: means a device consisting of 2 or more coils of insulated wire that transfers alternating current by electromagnetic induction from 1 coil to another to change the original voltage or current value.
2. Distribution Transformer: means 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 an—
        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
        xiii. Welding transformer.

B) Product Types:

1. Liquid-immersed Distribution Transformers: means a distribution transformer in which the core and coil assembly is immersed in an insulating liquid.

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

2. Low-voltage Dry-Type Distribution Transformer: means 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. Medium-voltage Dry-type Distribution Transformer: means 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) Operational Power States:

1. No-Load Loss (or Core Loss): means those losses that are incident to the excitation of the transformer.

2. Load Loss (or Coil Loss): means, for a distribution transformer, those losses 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. Total Loss: means the sum of the no-load loss and load loss for a transformer.

D) Basic Model: means 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.

Note: EPA is proposing the same definition of basic model as in the Department of Energy Final Rule Energy Conservation Program: Energy Conservation Standards for Distribution Transformers, 78 FR 23384, to eliminate unnecessary test burden for manufacturers. Later in the specification, EPA also proposes to allow the Alternative Efficiency Determination Method (AEDM) for certification. EPA welcomes feedback on any additional or alternate definitions as well as any other ways to reduce manufacturer burden.

2 SCOPE

2.1 Included Products

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

Note: EPA is proposing to include only Liquid-Immersed Distribution Transformers because, according to EPA findings outlined in the Medium Voltage Distribution Transformers Scoping Report[2], they represent the majority of sales in the market and have the greatest energy efficiency savings potential.

2.2 Excluded Products

2.2.1 Products that are covered under other ENERGY STAR product specifications are not eligible for qualification 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 qualification under this specification:

[2] U.S. Environmental Protection Agency, "ENERGY STAR Market and Industry Scoping Report: Medium Voltage Distribution Transformers", February 2014, http://www.energystar.gov/ia/products/downloads/MV_Utility_Distribution_Transformers_Scoping.pdf

i. Low-voltage Dry-Type Distribution Transformer;

ii. Medium-voltage Dry-type Distribution Transformer;

3 EFFICIENCY 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 Efficiency at Optimized Capacity Factor

3.2.1 The Percent Efficiency, calculated per Equation 1, shall be greater than or equal to the efficiency requirement specified in Table 1 for each relevant capacity factor.

i. For transformers with a kVA rating not listed in Table 1, the no-load and load losses at that kVA rating shall be entered into Equation 2 to calculate the losses for an equivalent transformer at a kVA rating that does appear in the table. These equivalent no-load and load losses shall be entered into Equation 1 to determine the Percent Efficiency of the equivalent transformer and compare against the efficiency requirement.

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

Equation 1: Percent Efficiency Calculation

$$\eta = 100\% \times \left(\frac{S_1 \times L \times 1000}{S_1 \times L \times 1000 + NL_1 + LL_1 \times L^2}\right)$$

Where:

- *η is efficiency of the transformer as a percentage;*
- *S_1 is the kVA rating of the transformer;*
- *L is the per unit load level, e.g., if the load level is 50%, then 'L' will be equal to 0.5;*
- *LL_1 is the load loss power corrected to the reference temperature of 55°C and incorporating ohmic and stray losses at the load level; and*
- *NL_1 is the no-load loss power corrected for wave-form distortion and then to the reference temperature of 20°C.*

Equation 2: Equivalent Losses for Transformers at Intermediate kVA Ratings

$$NL_1 = NL_0 \times \left(\frac{S_1}{S_0}\right)^x \text{ and } LL_1 = LL_0 \times \left(\frac{S_1}{S_0}\right)^x$$

Where:

- *LL_0 and NL_0 are the load and no-load losses, respectively, at an intermediate kVA rating S_0, measured per the Test Method;*
- *LL_1 and NL_1 are the load and no-load losses, respectively, at the equivalent kVA rating S_1 (for use in Equation 1);*
- *S_0 is an intermediate kVA rating not appearing in Table 1;*
- *S_1 is the closest kVA rating in Table 1 for which equivalent losses and Percent Efficiency are being calculated; and*
- *x is the scaling exponent, which is 0.76 for single-phase and 0.79 for three-phase.*

Example: To determine the applicable energy efficiency requirement for a 40 kVA single-phase transformer, use Equation 2 to determine the equivalent losses at the closest provided kVA rating in Table 1 (50 kVA). The equivalent losses are then used in Equation 1 to determine the efficiency requirement for the equivalent 50 kVA transformer.

Start with no-load losses of 135.89 W and load losses of 334.51 W for the 40 kVA transformer,

NL_{40} = 135.89 W

LL_{40} = 334.51 W

$NL_{50} = 135.89 \times \left(\frac{50}{40}\right)^{0.76}$ = 161.00 W

$LL_{50} = 334.51 \times \left(\frac{50}{40}\right)^{0.76}$ = 396.33 W

$\eta = 100\% \times \left(\frac{50 \times 0.5 \times 1000}{50 \times 0.5 \times 1000 + 161.00 + 396.33 \times 0.5^2}\right) = 98.97\%$

The efficiency for this equivalent kVA transformer would be 98.97%, which can then be compared to the energy efficiency requirement at 50 kVA and 50% capacity factor to determine if the original 40 kVA model would meet the criteria.

Table 1: Efficiency Requirements at Optimized Capacity Factors

	Number of Phases:	**Single-phase**			**Three-phase**	
	Capacity (kVA Rating):	**25**	**50**	**500**	**150**	**1500**
Efficiency at Specified Capacity Factor (%)	**10%**	TBD	TBD	TBD	TBD	TBD
	15%	TBD	TBD	TBD	TBD	TBD
	20%	TBD	TBD	TBD	TBD	TBD
	25%	TBD	TBD	TBD	TBD	TBD
	30%	TBD	TBD	TBD	TBD	TBD
	35%	TBD	TBD	TBD	TBD	TBD
	40%	TBD	TBD	TBD	TBD	TBD

	45%	TBD	TBD	TBD	TBD	TBD
	50%	TBD	TBD	TBD	TBD	TBD
	55%	TBD	TBD	TBD	TBD	TBD
	60%	TBD	TBD	TBD	TBD	TBD
	65%	TBD	TBD	TBD	TBD	TBD
	70%	TBD	TBD	TBD	TBD	TBD

Note: The ENERGY STAR product specification process relies on rigorous market, engineering and pollution savings analysis, and involvement from a range of stakeholders to develop product criteria that will yield significant energy savings on a national basis. The goal of this process is to establish ENERGY STAR requirements, consistent with program principles, such that products that meet them reduce greenhouse gas emissions and save purchasers money without sacrificing performance. When establishing eligibility criteria, EPA proposes levels that maintain product performance such that performance is not traded for efficiency. Additionally, the Agency sets specifications that enable purchasers to recover their investments in greater efficiency within a reasonable time period, and that ensure that more than one manufacturer can meet them, offering the end user multiple options in the market. Reflecting this process, EPA proposes an approach in its Draft 1 Specification for Distribution Transformers that will highlight the top performing products.

In response to the initial framework document released as part of this specification development process, EPA heard from stakeholders about the importance of optimizing transformers for their intended capacity factor, or load. A review of the Department of Energy's (DOE's) transformer data set (which includes over 6000 transformer designs) indicates that different transformers perform more efficiently at different capacity factors, i.e. some transformers perform more efficiently at lower capacity factors, whereas others perform more efficiently at higher ones. Given these circumstances, EPA is proposing to allow for ENERGY STAR certification at particular capacity factors, so that purchasers can easily identify highly efficient alternatives that meet their individual needs.

To this end, EPA proposes to set ENERGY STAR efficiency levels at each capacity factor from 10% to 70% (in 5% increments) that reflect the highest efficiency performance while maintaining a good selection of products across a variety of manufacturers at each capacity factor. In order for products to earn the ENERGY STAR label, they must deliver energy savings beyond the savings resulting from conventional products—those that just meet the DOE minimum efficiency standards. A transformer design could earn the ENERGY STAR label at one or more capacity factors. It is not EPA's intention to establish requirements such that only amorphous core technology qualifies.

At this time, EPA is assembling additional data to inform the specification setting process. Manufacturers are invited to provide modeled and tested data on their current models for inclusion in the dataset. In the absence of receiving new data, EPA will evaluate DOE's Final Rule dataset of transformer designs to propose levels at each capacity factor in Draft 2. In its forthcoming analysis EPA intends to exclude designs that do not meet the DOE 2016 Final Rule to ensure that it captures all new designs available in the market after January 1, 2016 when the Final Rule takes effect.

EPA will evaluate and propose energy efficiency requirements at all capacity factors based on data indicating which products perform most efficiently when optimized for each capacity factor.

EPA seeks feedback from stakeholders on this approach to developing criteria for a Transformers specification to differentiate products that deliver additional energy savings over the energy performance of conventional models. Overall, EPA's proposed approach will allow various technologies to qualify for ENERGY STAR, as different technologies deliver greater energy efficiencies at different capacity factors.

4 TESTING

4.1 Test Methods

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

Table 2: Test Methods for ENERGY STAR Qualification

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 laid out in the Department of Energy Certification Requirements for Distribution Transformers, 10 CFR 429.47.

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

ii. For qualification of all products under the Basic Model definition, the Alternative Efficiency Determination Method (AEDM) can be used to qualify all subsequent models that meet the Basic Model parameters. Any subsequent testing failures (e.g., as part of verification testing) of any model in this family of products will have implications for all models in the family.

iii. At least five of a manufacturer's Basic Models must be tested and power loss must be calculated. The predicted total power loss for each of these models, calculated by applying the AEDM must be within +/- 5% of the mean total power loss determined from testing.

iv. Manufacturers using the AEDM shall follow all verification methods and procedures laid out in Department of Energy Certification Requirements: Alternative methods for determining energy efficiency and energy use, 10 CFR 429.70(a), (b), and (d).

Note: To ensure consumer confidence in the ENERGY STAR label and to protect the investment of ENERGY STAR partners, in 2011, EPA introduced third-party certification and verification. EPA now requires all ENERGY STAR labeled products to be third-party certified, where products are tested in an EPA-recognized laboratory and reviewed by an EPA-recognized certification body (CB).

EPA intends for 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. The DOE test method for distribution transformers is referenced in the draft specification, which allows for testing to be performed at 0% and 100% capacity factor, and for performance at a specified capacity factor to be calculated. Consistent with DOE requirements, EPA would also allow for the use of an Alternative Efficiency Determination Method (AEDM). Documentation of calculated values for relevant capacity factors would be reviewed by an EPA-recognized certification body.

For purposes of ENERGY STAR certification, any testing would need to be performed in an accredited laboratory or one that participates in a CB's witnessed or supervised manufacturers' testing laboratory (W/SMTL) program. Laboratories that are accredited to ISO/IEC 17025 by an EPA-recognized accreditation body (AB) may apply for EPA recognition and unaccredited laboratories can gain EPA recognition by participating in a CB's witnessed W/SMTL program. For those distribution transformer manufacturers that operate their own laboratories for testing and are not accredited, EPA recommends that manufacturers participate in a CB's W/SMTL. More information on EPA's third party certification and verification program is available at www.energystar.gov/3rdpartycert.

4.3 International Market Qualification

4.3.1 Products shall be tested for qualification at the relevant input voltage/frequency combination for each market in which they will be sold and promoted as ENERGY STAR.

5 EFFECTIVE DATE

5.1.1 Effective Date: The Version 1.0 ENERGY STAR Distribution Transformers specification shall take effect on **TBD**. To qualify 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 qualification is not automatically granted for the life of a product model.