

SUMMARY OF DOE EFFICIENCY REGULATIONS

DOE Efficiency Regulations

DOE has adopted energy conservation standards for transformer efficiency and the test procedures related to determining transformer efficiency

- The DOE Standards are detailed in two Federal Register documents
 - Energy Conservation Standards (72FR58190, October 12, 2007)
 - Test Procedures (71FR24972, April 27, 2006)
- DOE's efficiency standards are mandatory and are effective on units built on or after January 1, 2010

DOE Specified (Represented) Efficiency and Allowed Tolerance

1. DOE Efficiency Levels (from 72FR58190, October 12, 2007, page 58239)

Single-Phase		Three-Phase	
kVA	DOE Specified Level	kVA	DOE Specified Level
10	98.62%	15	98.36%
15	98.76%	30	98.62%
25	98.91%	45	98.76%
37.5	99.01%	75	98.91%
50	99.08%	112.5	99.01%
75	99.17%	150	99.08%
100	99.23%	225	99.17%
167	99.25%	300	99.23%
250	99.32%	500	99.25%
333	99.36%	750	99.32%
500	99.42%	1000	99.36%
667	99.46%	1500	99.42%
833	99.49%	2000	99.46%
		2500	99.49%

2. Allowed Efficiency Tolerances (from 71FR24972, April 27, 2006, page 24998)

Just as IEEE C57.12.00-2006, Section 9.3 presently allows tolerances for losses (10% on No-Load and 6% on Total Loss), DOE allows tolerances for efficiency. The tolerance is calculated as follows:

- Average Efficiency Calculation

The average efficiency shall be greater or equal to the value as derived by the following equation:

$$\bar{X} \geq \frac{100}{1 + \left(1 + \frac{0.08}{\sqrt{n}}\right) \left(\frac{100}{RE} - 1\right)}$$

Where, n = number of units tested

RE = represented efficiency (DOE Specified Efficiency) as shown in the tables above

- Absolute Minimum Efficiency Calculation

The absolute minimum efficiency for any single unit may be calculated by using the above formula by setting $n = 1$.

- Using the above formula, examples of Average Efficiency Calculations for typical number of units (n) along with the absolute minimum (n=1), the following charts may be developed:

Single Phase						
kVA	Minimum Average Efficiency / Number of Units (n)					% Represented Efficiency (RE)
	1	10	50	100	300	
10	98.51	98.59	98.60	98.61	98.61	98.62
15	98.66	98.73	98.75	98.75	98.75	98.76
25	98.82	98.88	98.90	98.90	98.91	98.91
37.5	98.93	98.99	99.00	99.00	99.01	99.01
50	99.01	99.06	99.07	99.07	99.08	99.08
75	99.10	99.15	99.16	99.16	99.17	99.17
100	99.17	99.21	99.22	99.22	99.23	99.23
167	99.19	99.23	99.24	99.24	99.25	99.25
250	99.27	99.30	99.31	99.31	99.32	99.32
333	99.31	99.34	99.35	99.35	99.36	99.36
500	99.37	99.41	99.41	99.42	99.42	99.42
667	99.42	99.45	99.45	99.46	99.46	99.46
833	99.45	99.48	99.48	99.49	99.49	99.49

Table 1. Single Phase Efficiency Levels

Three Phase						
kVA	Minimum Average Efficiency / Number of Units (n)					% Represented Efficiency (RE)
	1	10	50	100	300	
15	98.23	98.32	98.34	98.35	98.35	98.36
30	98.51	98.59	98.60	98.61	98.61	98.62
45	98.66	98.73	98.75	98.75	98.75	98.76
75	98.82	98.88	98.90	98.90	98.91	98.91
112.5	98.93	98.99	99.00	99.00	99.01	99.01
150	99.01	99.06	99.07	99.07	99.08	99.08
225	99.10	99.15	99.16	99.16	99.17	99.17
300	99.17	99.21	99.22	99.22	99.23	99.23
500	99.19	99.23	99.24	99.24	99.25	99.25
750	99.27	99.30	99.31	99.31	99.32	99.32
1000	99.31	99.34	99.35	99.35	99.36	99.36
1500	99.37	99.41	99.41	99.42	99.42	99.42
2000	99.42	99.45	99.45	99.46	99.46	99.46
2500	99.45	99.48	99.48	99.49	99.49	99.49

Table 2. Three Phase Efficiency Levels

Suggested Wording for Transformer Specifications

Although it is not necessary to add wording to transformer specifications regarding DOE Standards, as transformer manufacturers must comply on transformers produced on or after January 1, 2010, suggested wording may be as follows:

“The transformer efficiency must meet the specified value listed in the DOE Energy Conservation Standard 72FR58190, October 12, 2007 with the allowed tolerances as defined in the DOE Test Procedures 71FR24972, April 27, 2006.”

Some transformer specifications presently require guaranteed maximum losses with no tolerance. Similar wording related to efficiency may be stated as follows:

“Transformers must comply with DOE Energy Conservation Standards and Test Procedures as defined in Federal Registers 72FR58190, October 12, 2007 and 71FR24972, April 27, 2006, except the DOE Specified Efficiency is to be the absolute minimum efficiency for any single unit”.

Because this statement requires the DOE Specified Values to be the absolute minimum for any single unit, it results in more costly transformers than if the DOE tolerances are allowed.

Efficiency levels that are even higher than DOE Standards may be specified, but the required levels must be clearly stated along with the allowed tolerance. Specified efficiency levels higher than DOE Standards will result in more costly transformers.

Efficiency Calculations

- Efficiency of a transformer is the ratio of the output power to the input power and equation is:

$$\%Eff = \frac{kVA * 1000}{kVA * 1000 + NL + LL} * 100$$

Where, kVA is the rated kVA

NL is the no-load loss

LL is the load loss at 100% load

- DOE efficiency is defined at 50% load with no-load loss at 20°C and load loss at 55°C, therefore the equation becomes:

$$DOE \%Eff = \frac{.5 * kVA * 1000}{.5 * kVA * 1000 + NL + LL} * 100$$

Where, NL = no load loss at 20°C

LL = load loss at 55°C and at 50% load

LL@50% load = LL at 100% load * .5²

Requirements of Compliance

1.0 Scope

1.1 Non-exempt

- 1.1.a Transformers manufactured on or after 1/1/2010
- 1.1.b 1Ø, 10 kVA through 833 kVA
- 1.1.c 3Ø 15 kVA thru 2500 kVA
- 1.1.d Input Voltage less than or equal to 34.5 kV
- 1.1.e Output Voltage less than or equal to 600 volts
- 1.1.f All 50 States and US territories including Washington D.C., Puerto Rico, USVI (St Thomas, St. Croix, St. Johns), Guam, Wake, Midway, etc.

1.2 Exempt

- 1.2.a Transformers manufactured before 1/1/2010
- 1.2.b Rebuilt and refurbished transformers
- 1.2.c Less than 10 kVA 1Ø and 15 kVA 3Ø
- 1.2.d Greater than 833 kVA 1Ø and 2500 kVA 3Ø
- 1.2.e Input Voltage greater than 34.5 kV
- 1.2.f Output Voltage greater than 600 volts
- 1.2.g Transformers shipped outside of US and US Territories; Costa Rica, Nicaragua, Ecuador, etc.