

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1. **Final Rules for Medium Voltage transformers issued 10/12/07**
2. **Timing**
3. **Tables**
4. **Severity**
5. **Parameters**
6. **Enforcement**
7. **Implications and issues: 10 of them!**
8. **Assignments**
9. **Next meeting**

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

IEEE/PES TRANSFORMERS COMMITTEE

TF TRANSFORMER EFFICIENCY AND LOSS EVALUATION (DOE ACTIVITY)

MEETING MINUTES

Westin Lombard Yorktown Center, Lombard, Illinois – October 27, 2009
Chairman: [Phil Hopkinson](#), Secretary: Scott Choinski

The Task Force on Dielectric Transformer Efficiency and Loss Evaluation (DOE Activity) was called to order at 1:50 PM. There were 75 attendees, 29 members, and 46 guests with 3 requesting membership. Reviewed the Agenda for the meeting, and the Minutes from the April 21, 2009 meeting in Miami, Florida were approved as written.

1. Mr. Hopkinson reviewed slides from his presentation titled "Distribution Transformer Energy Efficiency Task Force." The presentation is posted on the IEEE Transformer Committee Website under the Distribution Transformers Subcommittee.

Preview for Next DOE Rule as a result of lawsuit settlement:

- NOPR October 2011
- Final Rule October 2012
- Effective date 1/1/2016

Testing Method or Alternative Efficiency Determination Method (AEDM), a statistical based efficiency determination method. It is expected that most will choose AEDM. If Testing Method is used, 100% test for 5 units or less. If more than 5 units are produced, may test all units but must test at least 5 units of each basic model every approx. 180 days.

Dual Voltage Transformer Efficiency - Must be measured on the winding connection that produces the highest losses or at both voltages.

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Efficiency of any given batch of transformers is not finally determined until after they are built and tested. You will not know if you meet the DOE requirements until you test the units.

Action: It was requested to post the definition of basic model from DOE regulation in Phil's document.

Basic Model Selection for AEDM Substantiation – there was a disagreement on basic models for verifying AEDM method. Two of the basic models must be among the five basic models with the highest unit volumes of production in the prior year. The highest unit volumes of production may change between this year and next year. These models may not be DOE compliant this year, but will be DOE compliant next year. There was a disagreement if a model that is not DOE compliant this year can be used to verify AEDM.

Labeling – There is no labeling requirement in the rule. There is a proposed addition to C57.12.00. [A nameplate entry addition to line 24 that states "DOE compliant."](#)

No Compliance Statement or Certification Report required for Distribution Transformers. However, manufacturers should keep the following type of information available for inspection by DOE:

- Model description
- Type of transformer
- Number of phases
- Power rating
- BIL

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

- Least efficient Basic Model
- Most efficient Basic Model
- Predicted losses and efficiencies
- Required efficiency from table
- Compliance summary

2. New Business

There was no new business.

The next meeting is planned for the spring in Houston. The meeting adjourned at 3:20 PM.

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Final Rule for Medium Voltage transformers
issued Oct. 12, 2007 in Federal Register

Department of Energy

10 CFR Part 431

Subpart K – Distribution Transformers

Subpart T – Certification and Enforcement (Reserved - future)

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Effective Date: The effective date
of this rule was **November 13, 2007.**

Standards for liquid-immersed and
medium-voltage, dry-type distribution
transformers started

January 1, 2010.

For new units.

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Transformers affected: Primary Distribution to Secondary Distribution

1. Medium Voltage Liquid

- » 10-833 kVA 1 phase
- » 15-2500 kVA 3 phase

2. Medium Voltage Dry

- » 15-833 kVA 1 phase
- » 15-2500 kVA 3 phase

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Transformers affected:

Primary Distribution to Secondary Distribution

- (1) Has an input voltage of 34.5 kilovolts or less;**
- (2) Has an output voltage of 600 volts or less; and**
- (3) Is rated for operation at a frequency of 60 Hertz; however, the term “distribution transformer” does not include—**
 - (i) A transformer with multiple voltage taps, the highest of which equals at least 20 percent more than the lowest;**
 - (ii) A transformer that is designed to be used in a special purpose application and is unlikely to be used in general purpose applications, such as a drive transformer, rectifier transformer, autotransformer, Uninterruptible Power System transformer, impedance transformer, regulating transformer, sealed and non-ventilating transformer, machine tool transformer, welding transformer, grounding transformer, or testing transformer; or**
 - (iii) Any transformer not listed in paragraph (3)(ii) of this definition that is excluded by the Secretary by rule because—**
 - (A) The transformer is designed for a special application;**
 - (B) The transformer is unlikely to be used in general purpose applications; and**
 - (C) The application of standards to the transformer would not result in significant energy savings.**

Transformers affected:

Low-voltage dry-type distribution transformer means 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.**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Transformers Definitions:

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.

Underground mining distribution transformer

means a medium-voltage dry-type distribution transformer that is built only for installation in an underground mine or inside equipment for use in an underground mine, and that has a nameplate which identifies the transformer as being for this use only.

Uninterruptible power supply transformer means a transformer that is used within an uninterruptible power system, which in turn supplies power to loads that are sensitive to power failure, power sags, over voltage, switching transients, line noise, and other power quality factors.

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Excluded Products

Autotransformer
Drive (isolation) transformer
Grounding transformer
Machine-tool (control) transformer
Nonventilated transformer
Rectifier transformer
Regulating transformer
Sealed transformer
Special-impedance transformer
Testing transformer
Transformer with tap range of 20 percent or more
Uninterruptible power supply transformer
Welding transformer

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1-Phase kVA	DOE Final Rule	3-Phase kVA	DOE Final Rule
		15	98.36%
10	98.62%	30	98.62%
15	98.76%	45	98.76%
25	98.91%	75	98.91%
37.5	99.01%	112.5	99.01%
50	99.08%	150	99.08%
75	99.17%	225	99.17%
100	99.23%	300	99.23%
167	99.25%	500	99.25%
250	99.32%	750	99.32%
333	99.36%	1000	99.36%
500	99.42%	1500	99.42%
667	99.46%	2000	99.46%
833	99.49%	2500	99.49%

Liquid Filled Transformers
1 Phase & 3 phase
Efficiencies

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

kVA	TSL0 Ave. Base Case Eff.	TSL0 Min. Base Case Eff.	TSL1	TSL2	DOE Final Rule	TSL3	TSL4	DOE Final Rule	TSL5	TSL6
10	98.42%	97.77%	98.40%	98.40%		98.44%	98.48%	98.62%	98.69%	99.32%
15	98.57%	97.99%	98.60%	98.56%		98.59%	98.63%	98.76%	98.82%	99.39%
25	98.74%	98.23%	98.70%	98.73%		98.76%	98.79%	98.91%	98.96%	99.46%
37.5	98.86%	98.40%	98.80%	98.85%		98.88%	98.91%	99.01%	99.06%	99.51%
50	98.97%	98.56%	98.90%	98.90%		98.90%	99.04%	99.08%	99.19%	99.59%
75	99.04%	98.66%	99.00%	99.04%		99.06%	99.08%	99.17%	99.21%	99.59%
100	99.11%	98.75%	99.00%	99.10%		99.12%	99.14%	99.23%	99.26%	99.62%
167	99.22%	98.90%	99.10%	99.21%		99.23%	99.25%	99.25%	99.35%	99.66%
250	99.24%	98.89%	99.20%	99.26%	99.32%	99.36%	99.45%		99.69%	99.70%
333	99.29%	98.97%	99.20%	99.31%	99.36%	99.40%	99.49%		99.71%	99.72%
500	99.36%	99.07%	99.30%	99.38%	99.42%	99.46%	99.54%		99.74%	99.75%
667	99.40%	99.13%	99.40%	99.42%	99.46%	99.50%	99.57%		99.76%	99.77%
833	99.44%	99.18%	99.40%	99.45%	99.49%	99.52%	99.60%		99.77%	99.78%

1 Phase Liquid mostly Between TSL 4 & TSL 5

Approximate equivalent Loss evaluation, in \$/watt

NL \ltimes \$4.50, LL ~ \$1.00

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Closer Look at Single Phase losses

kVA	10	15	25	37.5	50	75	100	167
Efficiency	98.62	98.76	98.91	99.01	99.08	99.17	99.23	99.25
watts at 50% Load	69.97	94.17	137.75	187.48	232.14	313.85	387.99	630.98
Implied core watts	35	47	69	94	116	157	194	315
Load watts	35	47	69	94	116	157	194	315
Temp adjuster 85/55	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Full load wdg watts	154	208	304	414	512	693	856	1393
Design for tolerance								
4% lower loss target	67.2	90.4	132.2	180.0	222.9	301.3	372.5	605.7
Nominal Design Core watts	34	45	66	90	111	151	186	303
Nominal Design Winding Watts	34	45	66	90	111	151	186	303
Nominal Full Load Wdg watts	148	200	292	397	492	665	822	1337

Material Implications

1. M3 or better Core steel
2. Reduced flux and current densities

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

kVA	TSL0 Ave. Base Case Eff.	TSL0 Min. Base Case Eff.	TSL1	TSL2	DOE Final Rule	TSL3	DOE Final Rule	TSL4	TSL5	TSL6
15	98.06%	97.19%	98.10%	98.36%	98.36%	98.68%		98.68%	99.25%	99.31%
30	98.37%	97.64%	98.40%	98.62%	98.62%	98.89%		98.89%	99.37%	99.42%
45	98.53%	97.87%	98.60%	98.76%	98.76%	99.00%		99.00%	99.43%	99.47%
75	98.70%	98.12%	98.70%	98.91%	98.91%	99.12%		99.12%	99.50%	99.54%
112.5	98.83%	98.30%	98.80%	99.01%	99.01%	99.20%		99.20%	99.55%	99.58%
150	98.91%	98.42%	98.90%	99.08%	99.08%	99.26%		99.26%	99.58%	99.61%
225	99.02%	98.57%	99.00%	99.17%	99.17%	99.33%		99.33%	99.62%	99.65%
300	99.08%	98.67%	99.00%	99.23%	99.23%	99.38%		99.38%	99.65%	99.67%
500	99.19%	98.83%	99.10%	99.32%	99.25%	99.45%		99.45%	99.69%	99.71%
750	99.24%	98.97%	99.20%	99.24%		99.31%	99.32%	99.37%	99.66%	99.66%
1000	99.29%	99.04%	99.20%	99.29%		99.36%	99.36%	99.41%	99.68%	99.68%
1500	99.36%	99.13%	99.30%	99.36%		99.42%	99.42%	99.47%	99.71%	99.71%
2000	99.40%	99.19%	99.40%	99.40%		99.46%	99.46%	99.51%	99.73%	99.73%
2500	99.44%	99.23%	99.40%	99.44%		99.49%	99.49%	99.53%	99.74%	99.74%

3 Phase Liquid mostly Between TSL 2 & TSL 3

Approximate equivalent Loss evaluation, in \$/watt

NL ☒ \$3.00 , LL ☒ \$1.00

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

kVA	15	30	45	75	112.5	150	225	300
Efficiency	98.36	98.62	98.76	98.91	99.01	99.08	99.17	99.23
watts at 50% Load	125.05	209.90	282.50	413.25	562.44	696.41	941.56	1163.96
Implied core watts	63	105	141	207	281	348	471	582
Load watts	63	105	141	207	281	348	471	582
Temp adjuster 85/55	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Full load wdg watts	276	463	624	912	1241	1537	2078	2569
Design for tolerance								
4% lower loss target	120.0	201.5	271.2	396.7	539.9	668.6	903.9	1117.4
Nominal Design Core watts	60	101	136	198	270	334	452	559
Nominal Design Winding Watts	60	101	136	198	270	334	452	559
Nominal Full Load Wdg watts	265	445	599	876	1192	1476	1995	2466

Material Implications similar to single phase

1. M3 or better core steel
2. Reduced flux and current densities

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

kVA	500	750	1000	1500	2000	2500
Efficiency	99.25	99.32	99.36	99.42	99.46	99.46
watts at 50% Load	1889	2567	3221	4375	5429	6787
Implied core watts	945	1284	1610	2188	2715	3393
Load watts	945	1284	1610	2188	2715	3393
Temp adjuster 85/55	1.10	1.10	1.10	1.10	1.10	1.10
Full load wdg watts	4170	5667	7109	9658	11984	14980
Design for tolerance						
4% lower loss target	1813.6	2464.8	3091.8	4200.4	5212.1	6515.2
Nominal Design Core watts	907	1232	1546	2100	2606	3258
Nominal Design Winding Watts	907	1232	1546	2100	2606	3258
Nominal Full Load Wdg watts	4003	5440	6824	9271	11505	14381

Material Implications similar to single phase

1. M3 or better core steel
2. Reduced flux and current densities

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1-Phase kVA	DOE Final Rule			3-Phase kVA	DOE Final Rule			
	kV BIL	20-45	46-95		>96	kV BIL	20-45	45-95
15	98.10%	97.96		15				
25	98.33%	98.12		30				
37.5	98.49%	98.30		45	98.10%	97.96		
50	98.60%	98.42		75	98.33%	98.12		
75	98.73%	98.57	98.53	112.5	98.49%	98.30		
100	98.82%	98.67	98.63	150	98.60%	98.42		
167	98.96%	98.83	98.80	225	98.73%	98.57	98.53	
250	99.07%	98.95	98.91	300	98.82%	98.67	98.63	
333	99.14%	99.03	98.99	500	98.96%	98.83	98.80	
500	99.22%	99.12	99.09	750	99.07%	98.95	98.91	
667	99.27%	99.18	99.15	1000	99.14%	99.03	98.99	
833	99.31%	99.23	99.20	1500	99.22%	99.12	99.09	
				2000	99.27%	99.18	99.15	
				2500	99.31%	99.23	99.20	

Dry Types from TSL2

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Design Line	Type	# of Phases	KVA Range	Primary BIL	Primary Taps, Full Capacity	Secondary Voltage	Selected unit to represent Design Line	Typical Owners and Applications
1	Liquid Pad	1	25-167	≤95 kV	±2-2.5%	240/120 through 600V	50kVA, 65°C, ONAN, 1Φ, 60Hz, 12470GrdY/7200 -240/120V, 95 kV BIL	Mainly Utility Owned or influenced ¹ ; Residential and Small Commercial
2	Liquid Pole	1	10-167	≤95 kV	±2-2.5%	120/240 through 600V	25kVA, 65°C, ONAN, 1Φ, 60Hz, 12470GrdY/7200 -240/120V, 95 kV BIL	Mainly Utility Owned or influenced; Residential and Small Commercial
3	Liquid Pad	1	25-167	125-150 kV	±2-2.5%	240/120 through 600V	50kVA, 65°C, ONAN, 1Φ, 60Hz, 24940GrdY/14400 -240/120V, 125 kV BIL	Mainly Utility Owned or influenced; Residential and Small Commercial
4	Liquid Pole	1	10-167	125-150 kV	±2-2.5%	120/240 through 600V	25kVA, 65°C, ONAN, 1Φ, 60Hz, 24940GrdY/14400 -240/120V, 125 kV BIL	Mainly Utility Owned or influenced; Residential and Small Commercial
5	Liquid	1	250-833	≤95-150 kV	±2-2.5%	250-333 kVA: 120/240 through 2400/4160YV; 500-833 kVA: 277/480Y through 2400/4160YV	333kVA, 65°C, ONAN, 1Φ, 60Hz, 14400/24940Y – 277/480YV, 150 kV BIL	Mainly Utility Owned or influenced; Med and large C&I. Single phase overhead and Industrial purposes, perhaps in a bank of 3.
6	Liquid	3	30-225	≤95 kV	±2-2.5%	208Y/120-600V	150kVA, 65°C, ONAN, 3Φ, 60Hz, 12470Y/7200-208Y/120V, 95 kV BIL	Mainly Utility Owned or influenced; Residential apartments and small commercial buildings
7	Liquid	3	300-2500	≤95-150 kV	±2-2.5%	300-1000 kVA: 208Y/120 through 4160Y/2400V 1500-2500 kVA: 480Y/277 through 4160Y/2400V	1000kVA, 65°C, ONAN, 3Φ, 60Hz, 24940Δ-480Y/277V, 150 kV BIL	Electric Utility, Industrial or Commercial; Substations and Industrial applications, commercial buildings
8	Dry	1	15-333	10 kV	No Taps	120/240V	25kVA, 150°C, ANN, 1Φ, 60Hz, 480-120/240V, 10 kV BIL	Commercial or Industrial Facilities; C&I and multi-family residential, lighting, etc.
9	Dry	1	15-833	20-60 kV	±2-2.5%	15-333 kVA: 120/240V through 600V 500-833 kVA: 480 through 2400V	75kVA, 150°C, ANN, 1Φ, 60Hz, 2400-480V, 20 kV BIL	Comm. / Building Owners, Industrial Facilities; C&I and multi-family residential, lighting, etc.
10	Dry	1	15-833	95-150 kV	±2-2.5%	15-333 kVA: 120/240V through 600V 500-833 kVA: 480 through 2400V	500kVA, 150°C, ANN, 1Φ, 60Hz, 12470-480V, 95 kV BIL	Comm. / Building Owners, Industrial Facilities; C&I and multi-family residential, lighting, etc.

Design Lines in Analysis

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Methods manufacturers must use to determine efficiency:

- A. Testing Method or;
- B. **Alternative Efficiency Determination Method (AEDM), a statistical based efficiency determination method**

Most Manufacturers use AEDM

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Testing Method Requirements:

Test Procedure (431.197 (b)(2) and (b)(3)) for each basic model:

- **100% test for 5 units or less.**
- **If more than 5 units are produced, may test all units but must test at least 5 units of each basic model.**

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 or dry-type), 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, in basic impulse insulation level (BIL), and impedance are examples of differentiating electrical features that affect energy consumption.

Test results must conform to DOE requirements

Dual Voltage Transformer Efficiency

Must be measured on the winding connection that produces the highest losses or at both voltages.

1. Dual Voltage – generally lower voltage produces highest losses
2. For 120/240 V secondary – the 120 volt connection
 - a) This DOE requirement may necessitate 2 loss tests
 - i. Highest voltage for IEEE C57.12.00
 - ii. Highest losses for DOE 10CFR431
 - b) For 120/240 V, manufacturer must go inside the transformer to reconnect, then reconnect for 240 after test for shipment.

Efficiency of any given batch of transformers is not finally determined until after they are built and tested

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Compliance with DOE Efficiency (paragraph 431.197 (b)(3))

Sample Average Efficiency, \bar{X}

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$$

where X_i is the measured efficiency of unit i and n is the number of units tested, must satisfy the condition:

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

where RE is the represented efficiency

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Testing Method Requirements

1. **No limits on losses for individual units unless only one base model unit produced during 180 day period, then limit is ~8%**
2. **Base Model may be different than customer model number because:**
 - a) **Same Base Model could be produced for more than one customer;**
 - b) **Manufacturer could produce the same Base Model (i.e. same basic electrical interior with different accessories, but is still same Basic Model for DOE Efficiency requirements;**
 - c) **Manufacturer could change core steels for a customer but not change customer model number, but unit would be a different Base Model for DOE Efficiency requirements**
3. **Manufacturer must continue to update his records to include new test data in order to comply with paragraph 431.197 (b)(3)**

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM

- 1. Purpose:** Reduce testing burden on manufacturers
 - AEDM can be used to predict the energy performance
 - Basic Models rated through the application of an AEDM need not be 100% tested for DOE Efficiency compliance
- 2. Requires a computational method** such as a software design tool that predicts the energy consumption characteristics of its basic models
- 3. Derived from a mathematical model** that represents the electrical characteristics of a basic model
- 4. Based on engineering and statistical analysis,** computer simulation or modeling, or other analytic evaluation of performance data

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

AEDM (Alternative Efficiency Determination Method)

1. **The accuracy and reliability of an AEDM must be substantiated before it may be used to determine the efficiency of basic models**
2. **A particular AEDM may be applied only to rate basic models in one of the following groups of distribution transformers:**
 - a) • liquid-immersed transformers
 - b) • low-voltage dry-type transformers
 - c) • medium-voltage dry-type transformers
3. **The manufacturer must use either the Test Method or the AEDM method, but not both**

Manufacturer must substantiate its AEDM

- 1. Five or more Basic Models tested using the DOE test method that are in compliance with the efficiency standard**
- 2. Five or more units must be tested for each basic model**
- 3. The predicted losses must average within ± 5 percent of the measured losses for each basic model tested**
- 4. The average of the predicted losses for all models must be within ± 3 percent of the average measured losses**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Basic Model Selection for AEDM Substantiation

- 1. Two of the basic models must be among the five basic models with the highest unit volumes of production in the prior year**
- 2. No two basic models should have the same combination of power (kVA) and voltage ratings**
- 3. At least one basic model should be single-phase and at least one should be three-phase**
- 4. All 5 basic models chosen must comply with DOE efficiency requirements**

Note: When identifying these five basic models, any basic model that does not comply with Federal energy conservation standards for distribution transformers that may be in effect shall be excluded from consideration.

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Compliance with DOE Efficiency (paragraph 431.197 (b)(3))

Sample Average Efficiency, \bar{X}

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i$$

where X_i is the measured efficiency of unit i and n is the number of units tested, must satisfy the condition:

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

where RE is the represented efficiency

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM Substantiation:

Example: Basic Model #1:

- 25 kVA Pole
 - 12470 GrY single HV bushing
 - 120/240 V LV
1. 5 units picked at random and tested
 2. DOE Efficiency Level is 98.91% at 50%load
 3. **Actual average must not vary by more than $\pm 5\%$ of the calculated/predicted losses for the model**
 4. Actual average must meet X equation, which means average must have an efficiency no less than 98.87% @ 50% load
 5. Must test on 120 volt low voltage connection

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM Substantiation:

Example: Basic Model #2:

- 15 kVA Pole
 - 12470 GrY single HV bushing
 - 120/240 V LV
1. 5 units picked at random and tested
 2. DOE Efficiency Level is 98.76% at 50%load
 3. **Actual average must not vary by more than $\pm 5\%$ of the calculated/predicted losses for the model**
 4. Actual average must meet X equation, which means average must have an efficiency no less than 98.72% @ 50% load
 5. Must test on 120 volt low voltage connection

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM Substantiation:

Example: Basic Model #3:

- 50 kVA Pad
 - 12470 GrY single HV bushing
 - 240/120 V LV
1. 5 units picked at random and tested
 2. DOE Efficiency level is 99.08% at 50% load
 3. **Actual average must not vary by more than $\pm 5\%$ of the calculated/predicted losses for the model**
 4. Actual average must meet X equation, which means average must have an efficiency no less than 99.05% @ 50% load
 5. Test on the 240 volt LV connection

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM Substantiation:

Example: Basic Model #4:

- 150 kVA 3 Phase Pad
- 12470 GrY/ 7200 HV
- 208 Y/ 120 V LV

1. 5 units picked at random and tested
2. DOE Efficiency level is 99.08% at 50% load
3. **Actual average must not vary by more than $\pm 5\%$ of the calculated/predicted losses for the model**
4. Actual average must meet X equation, which means average must have an efficiency no less than 99.05% @ 50% load
5. Test on the 120 volt LV connection

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

AEDM Substantiation:

Example: Basic Model #5:

- 500 kVA 3 Phase Liquid-filled
 - 12470 GrY/ 7200 V HV
 - 480 Y/ 277 V LV
1. 5 units picked at random and tested
 2. DOE Efficiency level is 99.25% at 50% load
 3. **Actual average must not vary by more than $\pm 5\%$ of the calculated/predicted losses for the model**
 4. Actual average must meet X equation, which means average must have an efficiency no less than 99.21% @ 50% load
 5. Test on the 277 volt LV connection

AEDM Substantiation:

Basic Model Selection for AEDM Substantiation

Fleet Tolerance to Prediction with AEDM

Model #1 \pm 5%

Model #2 \pm 5%

Model #3 \pm 5%

Model #4 \pm 5%

Model #5 \pm 5%

Total Fleet \pm 3%

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

AEDM Substantiation:

Basic Model Selection for AEDM Substantiation

Summary of requirements

1. Each Model must be in compliance with standard.
2. Total Fleet must comply with standard
3. **AEDM Method and data maintained by each manufacturer.**
4. **DOE may request data at audit if noncompliance is suspected.**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Issue #1: Phase-in allowed

- **Manufacturers and importers must start 1/1/10**
- **Distributors and Manufacturers may sell old stock**

Issue #1: No Time Limit on Old Stock if produced or imported prior to 1/1/2010

Therefore, customers that only want DOE compliant units must so specify

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Issue #2: Enforcement

- **Honor System**
- **DOE beginning to become more active in enforcement**
- **Users are best source for identifying non-compliance**

Issue #2:

DOE Goal for Average Efficiency to meet Standard

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

ISSUE #3: Cost Implication to End User

A. Material Availability and cost

- 2008 impacts were huge due to inflation
- 2009-10 impact mitigated due to current recession/financial crisis
- 2011 impact may be more evident as stronger market returns and if inflation happens
- Larger/heavier units – additional material
- Larger windings – more process time

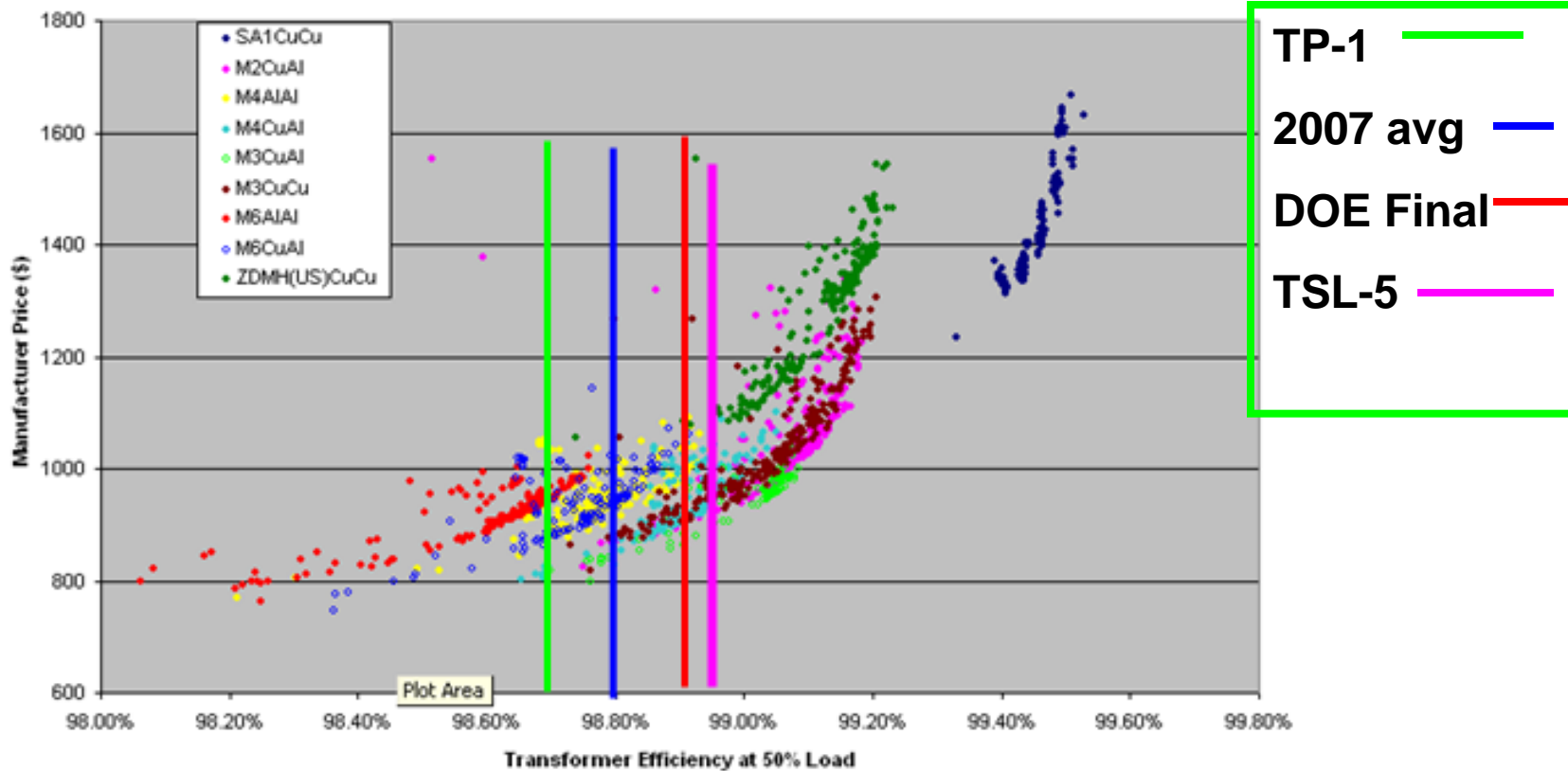
Issue #3: Cost versus 2007 Fleet

DOE Compliance additional material costs being mitigated

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

Engineering analysis design database for DL2, 25kVA single-phase liquid-type



DOE Engineering analysis predicts Final Rule compliance to add >20% to costs

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Issue #4: More capital-intensive constructions

1. Improved/thinner core steels – process time
2. Enhanced stress relief anneal processes
3. Compression bonded coils
4. Constructions for minimum stray losses
5. Additional wire and core sizes (Parts Proliferation) to obtain higher space factors
6. Winding and core equipment

**Issue #4: DOE Compliance may mean new investment,
new parts and more inventory**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

ISSUE #5 for Manufacturers who Test Method:
**Manufacturers must design lower average loss than
Final Rule**

1. Penalty for not meeting DOE efficiency levels may be severe
2. Meeting DOE efficiency requirements not an option
3. Manufacturing process controls must be improved
4. In past, manufacturers could work with users on units that did not meet losses, now units that do not meet DOE efficiency requirements cannot be shipped

**Issue #5: Design losses must average < DOE to meet
tolerance requirements**

ISSUE #6: Dual Voltage (HV) Transformers

- Typical 2400X7200 or 4160X7200 Volt ratings.
- Even ratios are not too problematic.
- Odd ratios result in unused windings.
- Cost and efficiency generally poorest on parallel connection.

**Issue #6 For manufacturers who use Test Method:
Must test both Connections – once for DOE, again for
IEEE**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Issue #7: 120/240 V connections-Loss measurement required on highest loss 120 V connection.

1. >98% of Transformers used in Series 120/240 V Connection
2. Parallel 120 V connection has circulating currents and may be 5-10% higher losses or ~0.1% lower efficiency.
3. Transformers on 240 Volt connection would need to be 0.1% higher efficiency to meet requirements on 120 volt connection.
4. Material impact ~3-5% to meet on all connections!

Issue #7 For Manufacturers who use 100% Test Method:

- Routine test 240 volt connection for IEEE
- Test 120 volt connection for DOE

Issue #8: Tolerance on Losses.

1. DOE different than IEEE C57.12.00
2. Goal is for units to average greater than or equal to DOE efficiency
3. When using Test Method – the following equation applies for an acceptable X bar, all units in model – even future units must comply:

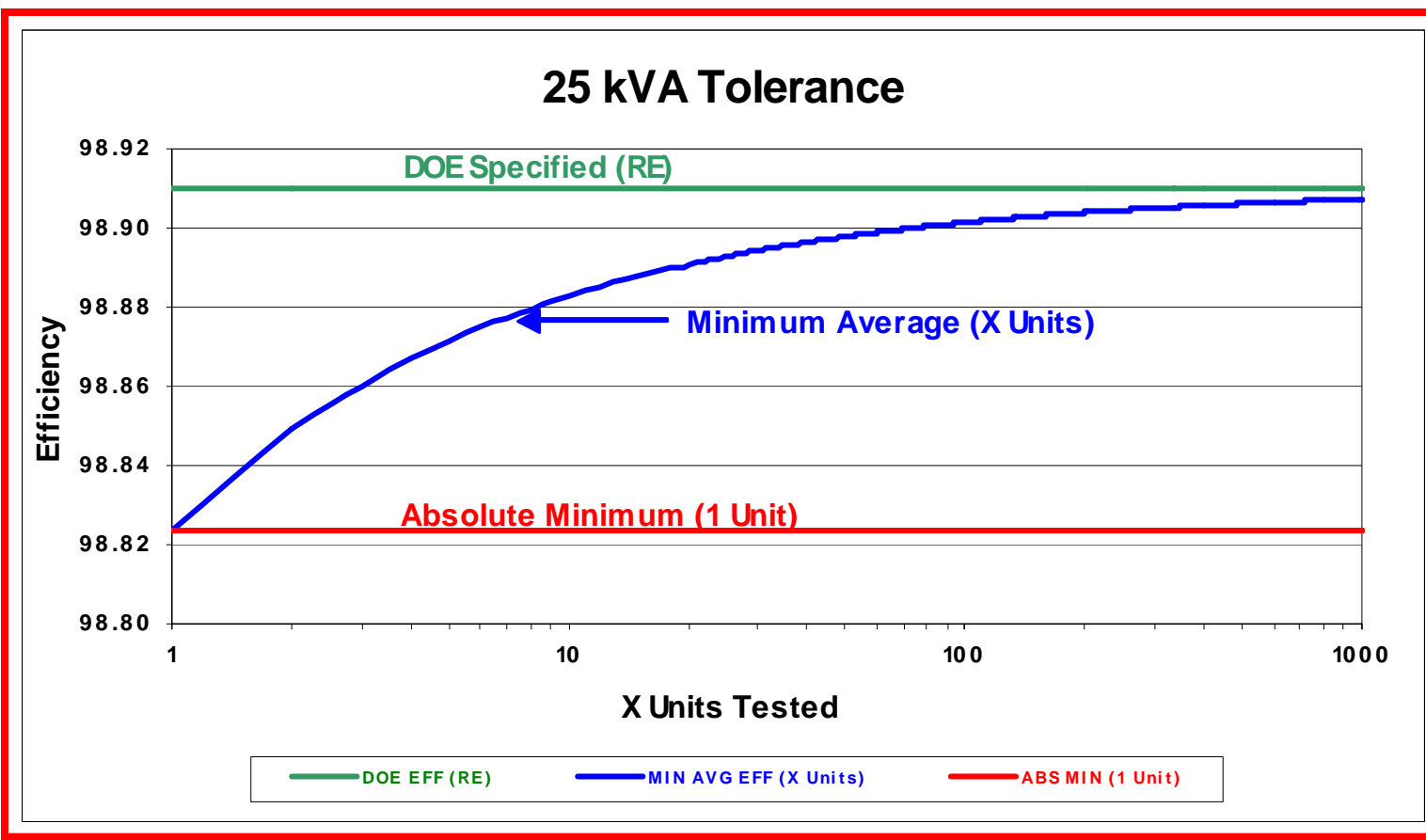
6/Rules and Regulations

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

where RE is the represented efficiency.

No limit on individual unit, unless only one unit produced

Issue #8: Tolerance on Losses.



Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

ISSUE #9: Labeling

- **Format – *No DOE Requirement* - Yet!!**

Common form on NP proposed:

**“DOE 10 CFR PART 431 10/27/07
COMPLIANT”**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

ISSUE #10: Compliance
Rely on users to determine non-compliance

New DOE Rules January 4, 2010:

1. Federal Register Vol 75, No.2 dated Tuesday, January 5, 2010
2. **Effective date of 180 days after publication of notice of OMB approval – OMB approval has not yet happened**

Compliance Statement
Certification Report

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Compliance Statement:

- (i) Each basic model complies and will comply with the applicable energy standard;
- (ii) All representations as to efficiency in the manufacturer's certification report(s) are and will be based on testing and/or use of an AEDM in accordance with 10 CFR Part 431;
- (iii) All information reported in the certification report(s) is and will be true, accurate, and complete; and
- (iv) The manufacturer or private labeler is aware of the penalties associated with violations of the Act ... which prohibits knowingly making false statements to the Federal Government

similar statement Mandatory

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Certification Report:

(ii) For the least efficient basic model of distribution transformer within each “kilovolt ampere (kVA) grouping”, the certification report shall include:

1. kVA rating
2. Insulation type (*i.e.*, low-voltage dry-type, medium-voltage dry-type or liquid-immersed)
3. Number of phases (*i.e.*, single-phase or three-phase)
4. BIL group rating (for medium-voltage dry-types)
5. Model number(s)
6. Efficiency, and the method used to determine the efficiency (*i.e.*, actual testing or an AEDM).

Certification Report Continued-2-:

As used in this section, a “kVA grouping” is a group of basic models which all have the same:

- 1. kVA rating**
- 2. Same insulation type (*i.e.*, low-voltage dry-type, medium-voltage dry-type or liquid-immersed)**
- 3. Same number of phases (*i.e.*, single-phase or three-phase)**
- 4. For medium-voltage dry-types, have the same BIL group rating, ie:**
 - 20–45 kV BIL**
 - 46–95 kV BIL**
 - >96 kV BIL.**

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Settlement of Environmental Lawsuit against DOE Distribution Transformer Rule

- **DOE to review current rule and decide if new rule is required/warranted**
- **If DOE decides new rules are warranted, will issue NOPR by 10/01/2011**
 - **Final Rule October 2012**
 - **Effective date 1/1/2016**

Many Issues to consider!

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

**Settlement of Environmental Lawsuit against
DOE Distribution Transformer Rule**

- **If DOE decides new rules are warranted, DOE to provide Final Rule by October 1, 2012**
- **This puts timing for new transformer efficiency rules under the present administration**

Environmentalists counting on higher efficiencies

Settlement of Environmental Lawsuit against DOE Distribution Transformer Rule

- **Effective date of any new DOE Transformer Efficiency rule is 1/1/2016**
- **Don't get complacent about this date, rules will be established over next 2 years, a very short time frame**

Obama administration pushing hard for increased energy efficiency

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Next Meeting

- **Toronto**
- **Assess Objectives in New Efficiencies**

Start thinking about Desires for Next Rule