

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1. **Final Rules for Medium Voltage transformers issued 10/12/07 and effective 1/1/2010.**
2. **General review**
3. **New Issues**
4. **Future Direction**
5. **Assignments**
6. **Next meeting**

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

MEETING MINUTES

Omni Houston Hotel, Houston, Texas – March 9, 2010

Chairman: Phil Hopkinson, Secretary: Scott Choinski

The Task Force on Dielectric Transformer Efficiency and Loss Evaluation (DOE Activity) was called to order at 1:45 PM. There were 76 attendees, 29 members, and 47 guests with 8 requesting membership. A quorum was present. There were no patents to disclose. The Minutes from the October 27, 2009 meeting in Lombard, Illinois, 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.

New DOE Rules for compliance issued January 4, 2010: Effective date of 180 days after publication of notice of OMB approval – OMB approval has not occurred yet.

Required to report on the least efficient model for each kVA grouping. If there is a new model that is less efficient, the manufacturer needs to resubmit for that kVA group.

Conducted a poll to see if manufacturers are using AEDM or Testing methods. Some are using AEDM and some are using Testing.

Environmental lawsuit against DOE on the grounds that carbon was not adequately monetized in the rulemaking. A settlement was reached to open the rulemaking process earlier, though the effective date for the new rules would remain unchanged. The rulemaking dates were picked to ensure rulemaking would occur under the current Administration. Sens. Lieberman, Kerry, McCain and Graham are pushing for environmental legislation. We may be able to influence assumptions for material costs, loading, energy costs, payback periods.

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Dates for the DOE Rulemaking as a result of lawsuit settlement:

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

Contractors involved in the original round of rulemaking have received new contracts for this round of rulemaking. DOE may be considering some aspects of efficiency rules from Motors. Motor manufacturers receive a certification number from DOE. The efficiency from the table along with the certification number may need to appear on the nameplate or another label on the transformer.

Some foreign manufacturers are not aware of the new regulations. These manufacturers would have a receiver in the US that would be liable for transformer efficiency.

Reviewed AEDM procedures.

Refurbished transformers are not covered by the DOE rule.

2. New Business

There was no new business.

The next meeting is planned for the fall in Toronto. The meeting adjourned at 3:20 PM.

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General Review

1.The rules for medium voltage	p.5
2.The tables	pp 12-18
3.Test methods	pp 20-36
4.Interpretations	pp 37-55
5.New Issues	pp 56-58
6.What's ahead	pp 59-70

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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)

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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.

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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

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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.**

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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.

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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

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1-Phase kVA	DOE Final Rule	3-Phase kVA	DOE Final Rule
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%

Liquid Filled Transformers
1 Phase & 3 phase
Efficiencies

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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 $\lt \times$ \$4.50, LL ~ \$1.00

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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

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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 \ltimes \$3.00 , LL \ltimes \$1.00

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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

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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

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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	>96
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

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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

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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

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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

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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

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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)**

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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

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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**

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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.

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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

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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

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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

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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

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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

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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%

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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.**

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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

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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

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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

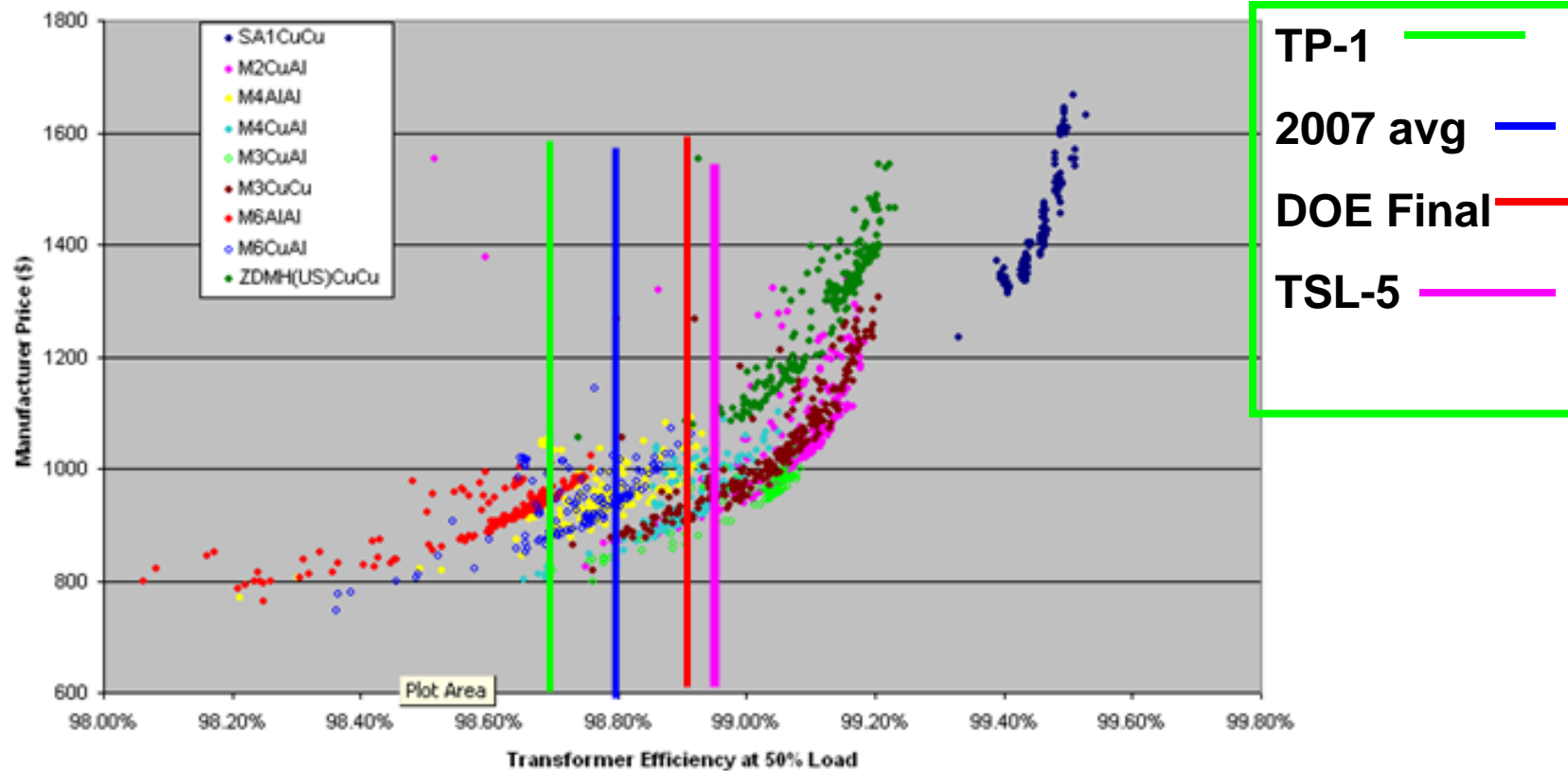
Issue #3: Cost versus 2007 Fleet

DOE Compliance additional material costs being mitigated

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



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

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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**

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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**

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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 \bar{X} bar, all units in model – even future units must comply:

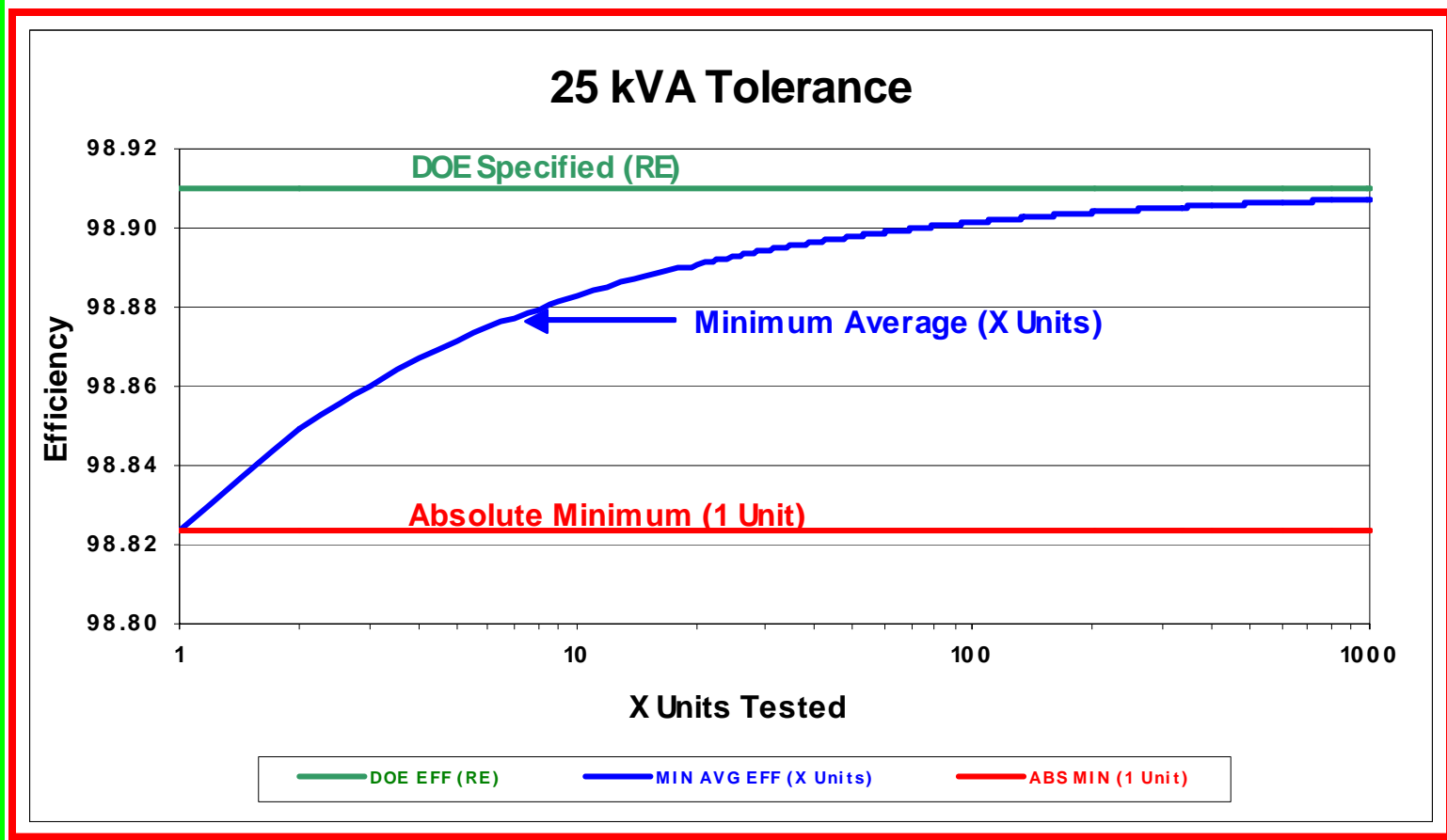
6 / Rules and Regulations

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

where RE is the represented efficiency.

No limit on individual unit, unless only one unit produced

Issue #8: Tolerance on Losses.



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ISSUE #9: Labeling

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

Common form on NP proposed:

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

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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

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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

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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.

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!

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**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

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The Toronto Meeting

- **Look at New Issues**
- **Learn about DOE plans for Next Rule**

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New Issues

- **Medium Voltage**
- **Low Voltage**
- **Labeling**
- **Certification and Enforcement**
- **Environmental Assumptions**
 - **Cost of materials**
 - **Loading**
 - **Energy cost**

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New Issues-Medium Voltage

- Lawsuit settlement by the environmentalists
- Requires Review of Efficiencies by October 1, 2011
- Standards may be raised or left unchanged
- Standards can never be lowered or dropped-called **Anti-backsliding**
- Economics and Impacts as well as new Best Technologies are basis for changes

Hope and Change is on the way

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New Issues-Medium Voltage-the review

- Life cycle costs
- Mfg. impact analysis including domestics versus foreign manufacturers and US jobs
- Government regulation impact
- National Impact analysis
 - Energy savings
 - \$ value

Many players involved

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The Players

- Navigant Consulting, especially Matt Hartley
- Lawrence Berkeley Lab
- NIST
- Optimized Program Services (OPS)
- Consultants
- Several offices within the DOE with Jim Raba
our central contact for transformers.

The Usual Suspects + A Few More

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New Issues-Medium Voltage-the schedule

- **Preliminary Analysis (ANOPR) estimated by 1st Q 2011**
- **ANOPR by October 1, 2011**
- **NOPR by October 1, 2012**
- **Implementation by 1/1/2016**

Criteria for change not yet published

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New Issues-Medium Voltage-the elements

- **Current Market Size**
- **Cost of Materials**
- **Cost of Energy**
- **Transformer loading assumptions**
- **Best Technologies**
- **Manufacturing Impact**
- **Market Impact**
- **National Impact**

Many players and studies in process

New Issues-Medium Voltage-Market Size Summary

- First study used 2001 and earlier data
- Current study used 2009 data
- 1-phase transformer units and MVA down 30% reflecting very depressed housing market
- 3-phase liquid transformer units and MVA down 37.5% due to depressed construction industry
- MV Dry units and MVA up 25% partly due to buy aheads but 2010 is considerably weaker
- LV Dry units and sales down 33% more reflective of the construction industry

Future projections are not strong as currently seen

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Medium Voltage-Other thoughts

- Lawrence Berkeley Lab examining cost of materials, loading and energy costs.
- Office of certification, enforcement and labeling headed by Ashley Armstrong at the DOE collecting data so far.
- Navigant Consulting examining market size, best technologies, and design optimization.
- OPS running designs
- Amorphous core, electronic transformer, Hexaformer technology and other being examined.
- Rush on to finish recommendations by 1st Q, 2011

Engineering Analysis to be updated

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New Issues-Low Voltage

- Last updated in 2006 and based on NEMA TP-1
- DOE has 6-7 year review requirement
- Can either reissue or increase efficiency requirements
- Backsliding not permissible
- NEMA Premium Efficiency is one door-opener
- Attempt underway to synchronize LV publications with MV
- Same Rush on to finish by 1st Q, 2011

**DOE Preliminary Analysis for both MV and LV may be
issued by Spring IEEE Transformers Committee
Meeting in San Diego**

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New Issues-IEC TC 14

- Energy Efficiency is on agenda for November 18-19, 2010 meeting in Beijing.
- Michel Sacotte of France to be Convener (working group leader)
- Work will address Medium Voltage Liquid and Dry.
- Task force being formed- delegates being solicited
- Contact Phil Hopkinson if you are interested.
- I will be the fall-back delegate by correspondence.

What efficiency levels and methods do we wish to propose to IEC?

Remember both 50 Hz and 60 Hz

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Next meeting in San Diego

- **New DOE Preliminary Analysis should be issued by March-April of 2011.**
- **We will have < 6 months to react and give meaningful comments**
- **We may wish to coordinate comments through:**
 - **NEMA**
 - **EEI**
 - **IEEE**
- **I will continue to collect issues and circulate to all groups.**

Cohesive Group Efforts and Communications may prove to be more useful than individual comments for real influence on DOE and IEC Standards.

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Materials to be posted

- DOE Energy Efficiency slides on my site under Distribution Transformers Subcommittee Website
- Updates will be posted as new information is available
- This taskforce should remain active through 2012
- Phil Hopkinson or Scott Choinski will collect issues
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 - 704-846-3290
 - Sco.choinski@nema.org
 - 703-841-3253