Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1. Introductions
   - Matt Hartley-Navigant Consulting
   - Hisham Araji-Navigant Consulting
2. Minutes from Toronto
3. Review-Final Rules from 2010.
4. New Issues for 2011
5. Future Direction
6. Assignments
7. Next meeting in Boston

MEETING MINUTES

Hilton Toronto Downtown, Toronto, Canada – October 26, 2010
Chairman: Phil Hopkinson, Secretary: Scott Choinski

The Task Force on Dielectric Transformer Efficiency and Loss Evaluation (DOE Activity) was called to order at 3:15 PM. There were 70 attendees, 26 members, and 44 guests with 5 requesting membership. A quorum was present. There were no patents to disclose. The Minutes from the March 9, 2010 meeting in Houston, Texas, 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.

   1.1. MVDT and Liquid-immersed transformers

   Current DOE energy efficiency rules are stringent, falling between TSL-4 and TSL-5 for

   - TSL-1: The NEMA TP 1 standard level
   - TSL-2: 1/3 of difference between TP 1 and minimum LCC (TSL-4)
   - TSL-3: 2/3 of difference between TP 1 and minimum LCC (TSL-4)
   - TSL-4: Minimum LCC (Life-Cycle Cost)
   - TSL-5: Maximum energy savings with no change in LCC
   - TSL-6: Maximum energy savings

Environmental groups did not feel that the efficiency levels were stringent enough and filed a 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. Dates for the DOE Rulemaking as a result of lawsuit settlement:

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

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 (no backsliding).

Preliminary Analysis for the ANOPR being conducted by Navigant Consulting, Lawrence Berkeley Lab and others. Exploring issues such as cost of materials, loading and energy costs, market size, best technologies, design optimization, amorphous core, electronic transformer, hexaformer technology and others. Estimated to be released by 1st Q 2011.

1.2. LVDT transformers

Last updated in 2006 and based on NEMA TP-1. DOE has 6-7 year review requirement. Attempt underway to synchronize LV publications with MV and estimated to be released by 1st Q, 2011

NEMA Premium Efficiency is one option to consider.

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1.3. IEC Standard for Energy Efficiency

It was noted that the IEC TC14 is starting to address energy efficiency for distribution transformers. It will be discussed at their next meeting November 2010 in Beijing. Michel Sacotte of France to be Convener (working group leader). Work will address Medium Voltage Liquid and Dry and is will be based on existing standards.

Working Group delegates from the US are being solicited. Contact Phil Hopkinson if you are interested.

2. New Business

There was no new business.

The next meeting is planned for the spring in San Diego. The meeting adjourned at 4:33 PM.

Reported by: Scott Choinski, October 26, 2010

General Review

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.

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.

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

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 ⌫ $4.50, LL ~ $1.00

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**

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

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

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

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

Sample Average Efficiency, X

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

where Xi 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

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)

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

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

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.

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

Sample Average Efficiency, X

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

where **Xi 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

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 ± 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**

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 ± 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**

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 ± 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**

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 ± 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 ± 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 ± 5%

Model #2 ± 5%

Model #3 ± 5%

Model #4 ± 5%

Model #5 ± 5%

Total Fleet ± 3%

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.**

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

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

ISSUE #3: Cost Implication to End User

A. Material Availability and cost

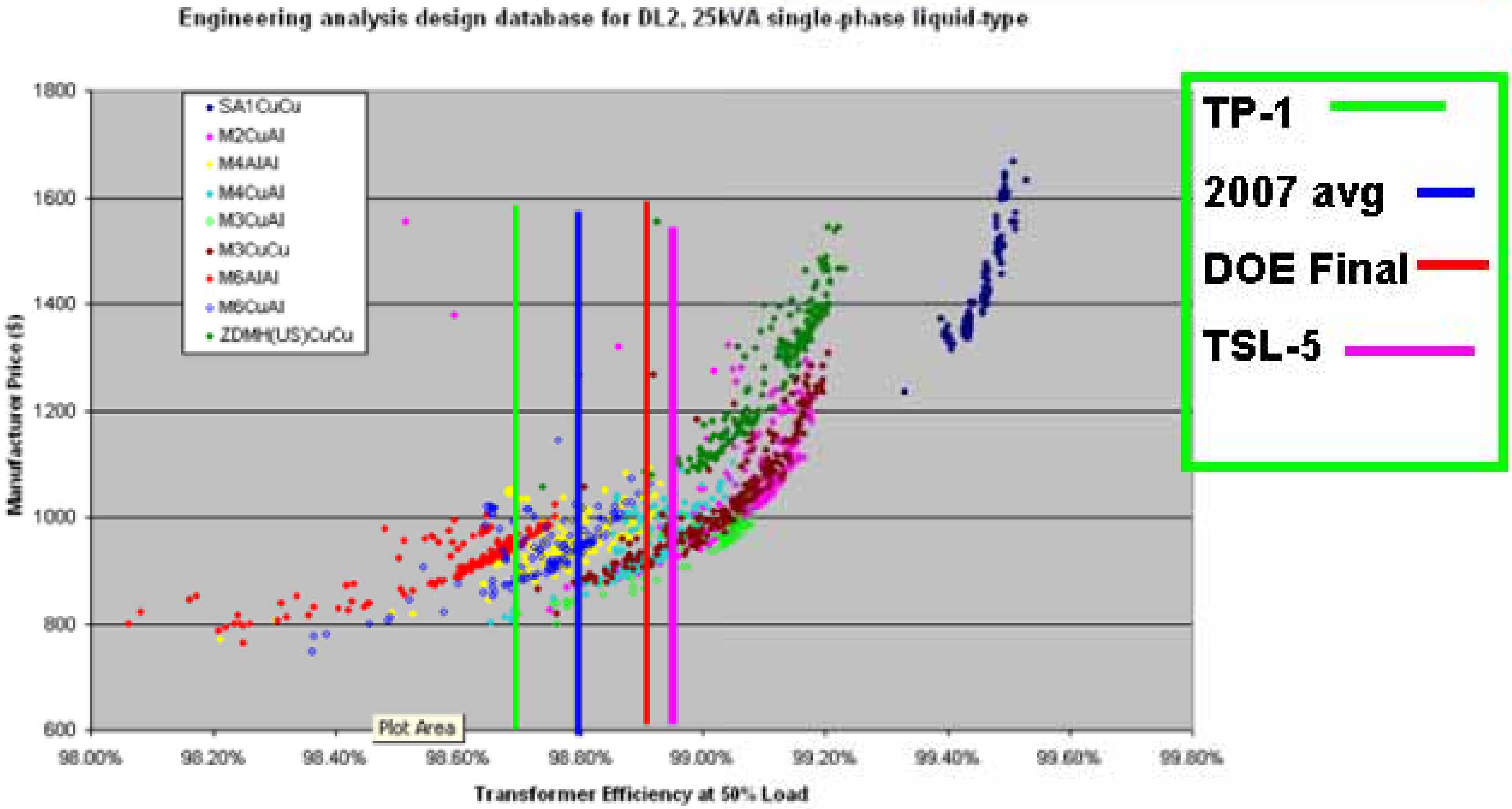
- 2008 impacts were huge due to inflation
- 2009-10 impact mitigated due to current recession/financial crisis
- 2011 impact may be more evident as stronger market returns and if inflation happens
- Larger/heavier units – additional material
- Larger windings – more process time

Issue #3: Cost versus 2007 Fleet

DOE Compliance additional material costs being mitigated

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE



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

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

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

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

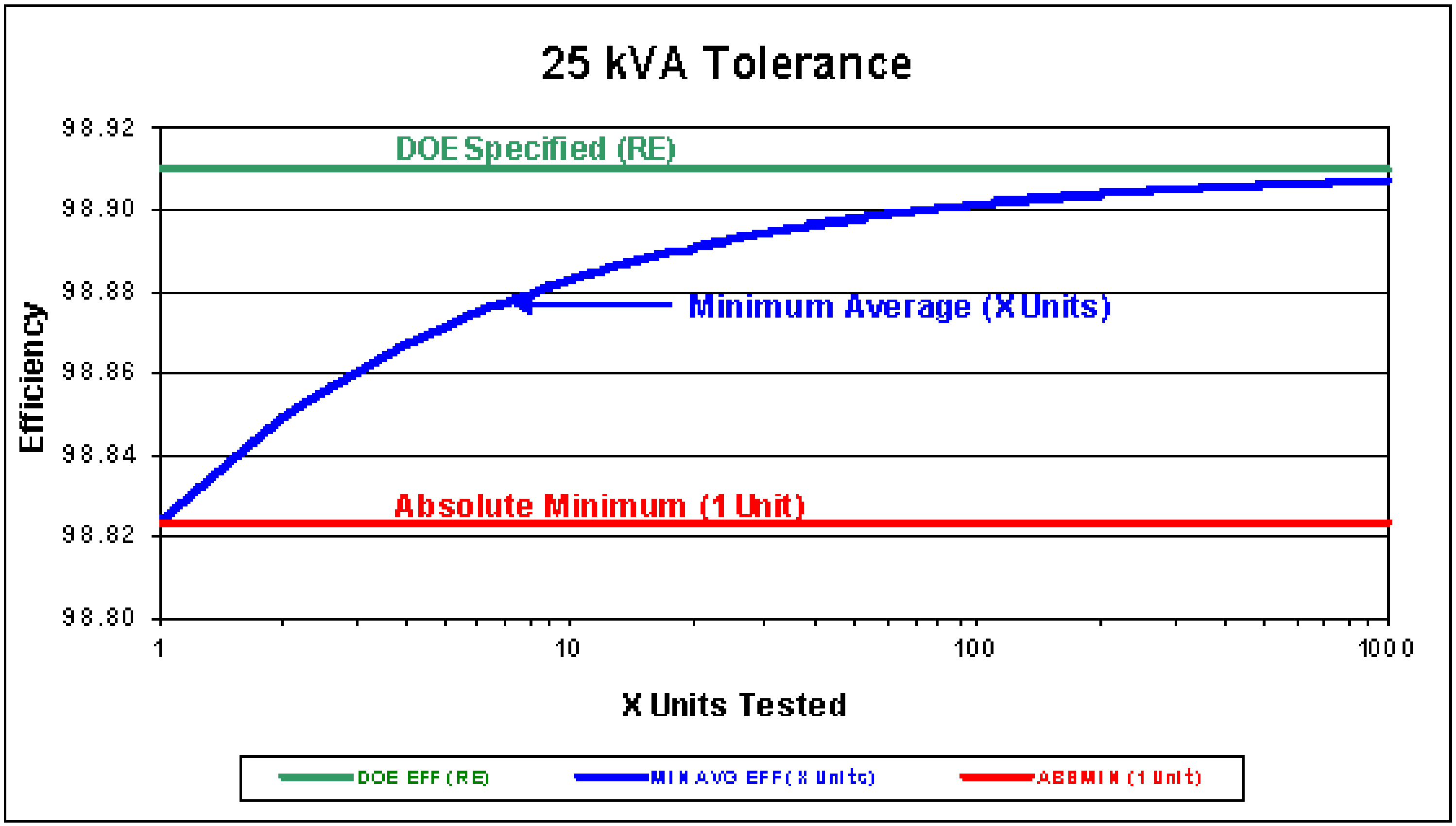
$$\bar{X} \geq \frac{100}{1+\left(1+\frac{0.08}{\sqrt{n}}\right)\left(\frac{100}{RE}-1\right)}$$

where RE is the represented efficiency.

No limit on individual unit, unless only one unit produced

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

Issue #8: Tolerance on Losses.



ISSUE #9: Labeling

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

Common form on NP proposed:

"DOE 10 CFR PART 431 10/27/07 COMPLIANT"

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

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

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!

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

The San Diego Meeting

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

New Issues

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

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

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

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

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

New Issues-Medium Voltage-the schedule

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

Criteria for change not yet published

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

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

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

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

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

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.

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.

San Diego Meeting April 12, 2011

1. **New April 5, 2011 DOE Preliminary Analysis issued and discussed in public meeting.**
2. **DOE relooking standards based on:**
   a. 2010 material prices
   b. New technologies examined
   c. New electricity costs based on EIA Projections
   d. Same loadings as 2010: 35% LV and 50% MV
   e. Alternative loadings at 0%, 15%, 35%, 50% and 75% load
   f. Life cycle costs based on 32 years
3. **New Technologies for consideration**
4. **Certification Requirements**

2010 Material prices Liquid

Table 5.4.1 Typical Manufacturer's Material Prices for Liquid-Immersed Design Lines

Material	Units	2010 Price *2010$*	2006 Price (Min.) *2010$*	2008 Price (Max.) *2010$*	2010 *2010$*	2009 *2010$*	2008 *2010$*	2007 *2010$*	2006 *2010$*
M6 core steel	$/lb	1.46	1.10	1.70	1.46	1.61	1.70	1.47	1.10
M5 core steel	$/lb	1.51	1.15	1.74	1.51	1.64	1.74	1.49	1.15
M4 core steel	$/lb	1.59	1.20	1.78	1.59	1.68	1.78	1.52	1.20
M3 core steel	$/lb	1.88	1.23	2.02	1.88	1.93	2.02	1.38	1.23
M3 core steel (Lite Carlite)	$/lb	1.95	0.00	0.00	1.95	0.00	0.00	0.00	0.00
M2 core steel	$/lb	2.00	1.54	2.16	2.00	1.98	2.16	2.02	1.54
M2 core steel (Lite Carlite)	$/lb	2.10	0.00	0.00	2.10	0.00	0.00	0.00	0.00
ZDMH (mechanically-scribed core steel)	$/lb	2.05	1.64	2.49	2.05	1.99	2.49	2.12	1.64
SA1 (amorphous) finished core, volume production	$/lb	2.38	0.00	2.82	2.38	2.26	2.82	0.00	0.00
Copper wire, formvar, round #10-20	$/lb	3.94	3.91	4.69	3.94	3.33	4.69	4.39	3.91
Copper wire, enameled, round #7-10	$/lb	4.35	4.35	4.82	4.35	3.48	4.82	4.52	4.35
Copper wire, enameled, rectangular sizes	$/lb	4.31	3.41	4.20	4.31	3.55	4.20	3.95	3.41
Aluminum wire, formvar, round #9-17	$/lb	3.65	2.32	2.71	3.65	2.55	2.71	2.40	2.32
Aluminum wire, formvar, round #7-10	$/lb	3.34	2.36	3.37	3.34	3.17	3.37	3.02	2.36
Copper strip, thickness range 0.02-0.045	$/lb	4.25	3.87	4.17	4.25	3.08	4.17	4.31	3.87
Copper strip, thickness range 0.030-0.060	$/lb	4.22	3.85	4.14	4.22	3.05	4.14	4.28	3.85
Aluminum strip, thickness range 0.02-0.045	$/lb	1.57	1.72	1.87	1.57	1.51	1.87	1.86	1.72
Aluminum strip, thickness range 0.045-0.080	$/lb	1.58	1.76	1.93	1.58	1.57	1.93	1.90	1.76
Kraft insulating paper with diamond adhesive	$/lb	1.52	1.36	1.49	1.52	1.52	1.49	1.45	1.36
Mineral oil	$/gal	3.35	2.26	2.97	3.35	2.85	2.97	2.33	2.26
Tank Steel	$/lb	0.38	0.38	0.47	0.38	0.38	0.47	0.40	0.38

2010 Material prices Dry

Table 5.4.4 Manufacturer's Material Prices for Dry-Type Design Lines

Material	Units	2010 Price *2010$*	2006 Price (Min.) *2010$*	2008 Price (Max.) *2010$*	2010 *2010$*	2009 *2010$*	2008 *2010$*	2007 *2010$*	2006 *2010$*
M12 core steel	$/lb	1.03	0.99	1.24	1.03	1.08	1.24	1.14	0.99
M6 core steel	$/lb	1.46	1.10	1.70	1.46	1.61	1.70	1.47	1.10
M5 core steel	$/lb	1.51	1.15	1.74	1.51	1.64	1.74	1.49	1.15
M4 core steel	$/lb	1.59	1.20	1.78	1.59	1.68	1.78	1.52	1.20
M3 core steel	$/lb	1.88	1.23	2.02	1.88	1.93	2.02	1.58	1.23
M2 core steel	$/lb	2.00	1.54	2.16	2.00	1.98	2.16	2.02	1.54
H-0 DR core steel (laser scribed)	$/lb	2.06	1.65	2.50	2.06	2.34	2.50	2.10	1.65
SA1 (amorphous) finished core, volume production	$/lb	2.38	0.00	2.82	2.38	2.26	2.82	0.00	0.00
Copper wire, rectangular 0.1 x 0.2, Nomex wrapped	$/lb	4.63	4.63	5.46	4.63	3.87	5.46	5.20	4.63
Aluminum wire, rectangular 0.1 x 0.2, Nomex wrapped	$/lb	2.19	1.43	1.62	2.19	1.53	1.62	1.49	1.43
Copper strip, thickness range 0.02-0.045	$/lb	4.25	3.87	4.17	4.25	3.08	4.17	4.31	3.87
Aluminum strip, thickness range 0.02-0.045	$/lb	1.57	1.72	1.87	1.57	1.51	1.87	1.86	1.72
Nomex insulation	$/lb	24.50	15.99	22.47	24.50	24.37	22.47	19.18	15.99
Cequin insulation	$/lb	5.53	4.48	4.71	5.53	5.04	4.71	4.76	4.48
Impregnation	$/gal	22.55	20.00	21.14	22.55	22.38	21.14	20.59	20.00
Winding combs	$/lb	12.34	7.08	11.93	12.34	12.51	11.93	11.11	7.08
Enclosure Steel	$/lb	0.38	0.38	0.47	0.38	0.38	0.47	0.40	0.38

2010 Material prices

Mission for Material Prices:

Examine list and comment on validity

1. **Copper Wire**
2. **Copper Foil**
3. **Aluminum**
4. **Magnetic Steel**
5. **Others**

With Comex copper at $4.30/lb, copper strip and copper foil must exceed $5.50/lb

Future loading assumption

Two possible considerations

1. **Traditional 35% for LV and 50% for MV**
2. **New LV possible consideration**
   - 0% Load
   - 15% Load
   - 35% Load
   - 50% Load
   - 75% Load

Base consideration continues 35% load LV and 50% Load MV

Future Energy Cost projection

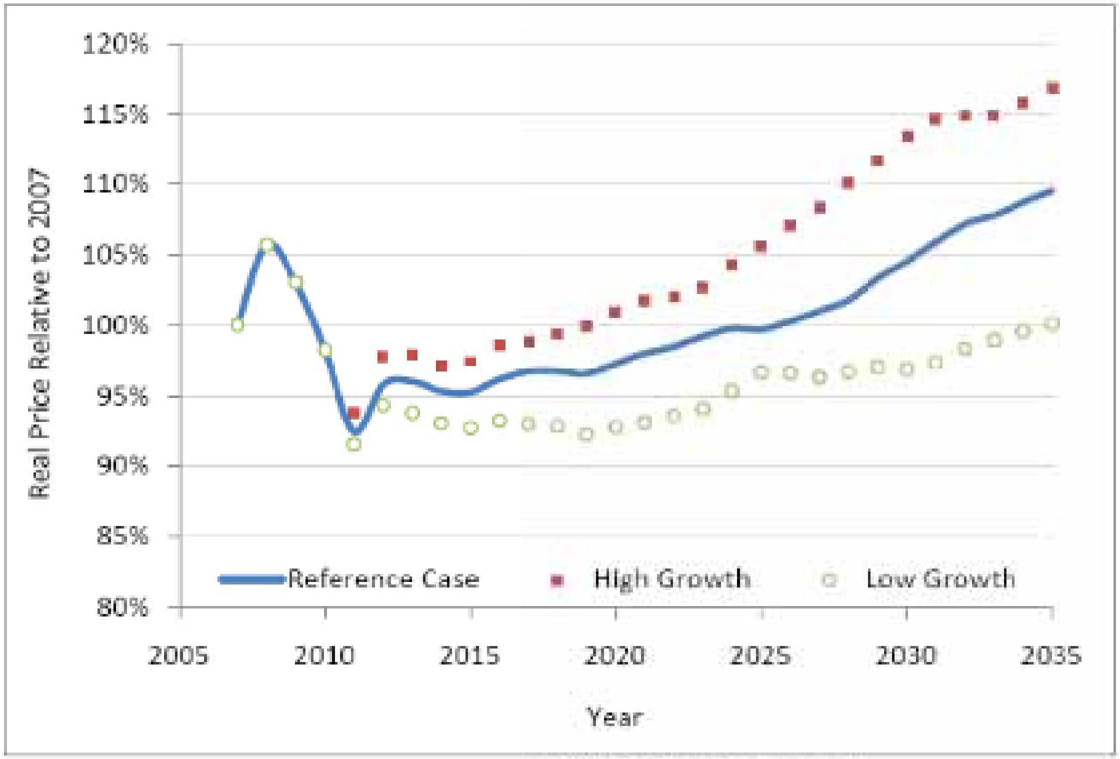


Figure 8.3.3 AEO 2010 Electricity Price Forecasts

Based on EIA projections

Future Incremental Transformer Selling Price vs. CSL

Table 5.5.2 Summary of Incremental Manufacturer Selling Prices Over the Baseline for Distribution Transformer Representative Units

Design Line	Representative Unit	Baseline	CSL1	CSL2	CSL3	CSL4	CSL5	CSL6	CSL7
		$	$	$	$	$	$	$	$
1	50 kVA, 65°C, single-phase, 60Hz, 14400V primary, 240/120V secondary, rectangular tank	-	234	501	578	854	1,406	2,109	N/A
2	25 kVA, 65°C, single-phase, 60Hz, 14400V primary, 120/240V secondary, round tank		235	416	605	751	1,312	N/A	N/A
3	500 kVA, 65°C, single-phase, 60Hz, 14400V primary, 277V secondary	-	675	2,386	2,246	3,005	4,544	7,140	11,922
4	150 kVA, 65°C, three-phase, 60Hz, 12470Y/7200V primary, 208Y/120V secondary	-	364	331	764	1,313	2,750	4,286	N/A
5	1500 kVA, 65°C, three-phase, 60Hz, 24940GrdY/14400V primary, 480Y/277V secondary	-	1,663	5,509	6,040	6,694	10,613	43,740	N/A
6	25 kVA, 150°C, single-phase, 60Hz, 480V primary, 120/240V secondary, 10kV BIL	-	(2)	146	264	303	452	591	1,219
7	75 kVA, 150°C, three-phase, 60Hz, 480V primary, 208Y/120V secondary, 10kV BIL	-	18	117	288	565	1,171	1,294	2,703
8	300 kVA, 150°C, three-phase, 60Hz, 480V Delta primary, 208Y/120V secondary, 10kV BIL	-	520	1,037	2,734	3,730	7,334	N/A	N/A
9	300 kVA, 150°C, three-phase, 60Hz, 4160V Delta primary, 480Y/277V secondary, 45kV BIL	-	828	2,780	4,189	5,443	9,715	N/A	N/A
10	1500 kVA, 150°C, three-phase, 60Hz, 4160V primary, 480Y/277V secondary, 45kV BIL		5,561	9,469	12,907	14,341	31,275	N/A	N/A
11	300 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 95kV BIL	-	460	2,079	3,861	5,617	10,715	N/A	N/A
12	1500 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 95kV BIL	-	2,567	5,170	11,072	12,556	19,192	33,255	N/A
13	2000 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 125kV BIL	-	3,929	10,513	18,017	24,196	44,046	N/A	N/A

Base is the 2010 energy efficiency requiremnet

They may get a lot more expensive

Future Transformer Selling Price

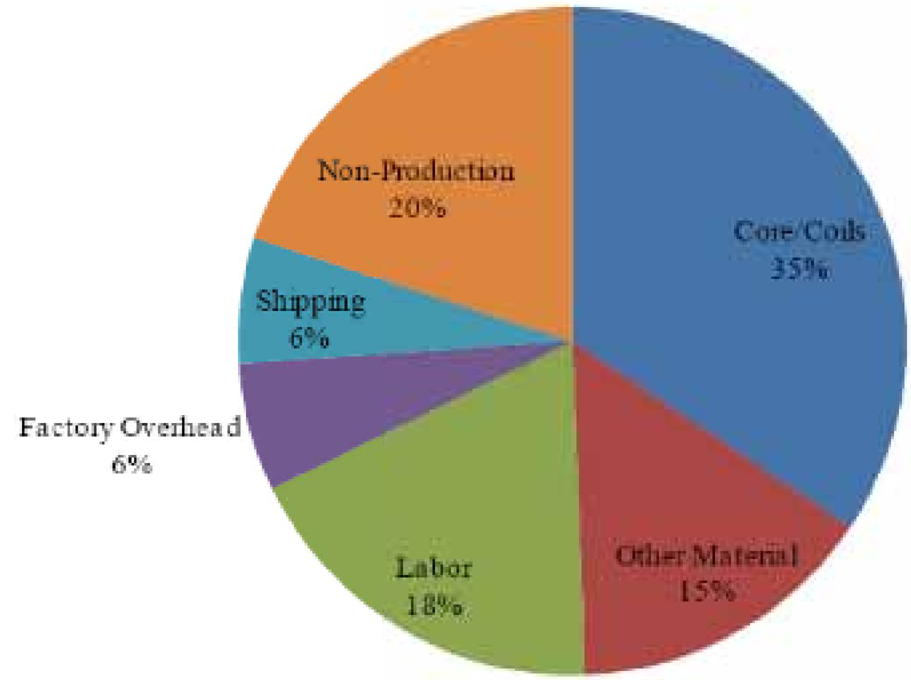


Figure 5.7.2 Manufacturer Selling Price Breakdown, Transformer from Design Line 7

Base is the 2010 energy efficiency requirement

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

50 kVA 1Φ Pad Transformer Selling Price vs. CSL

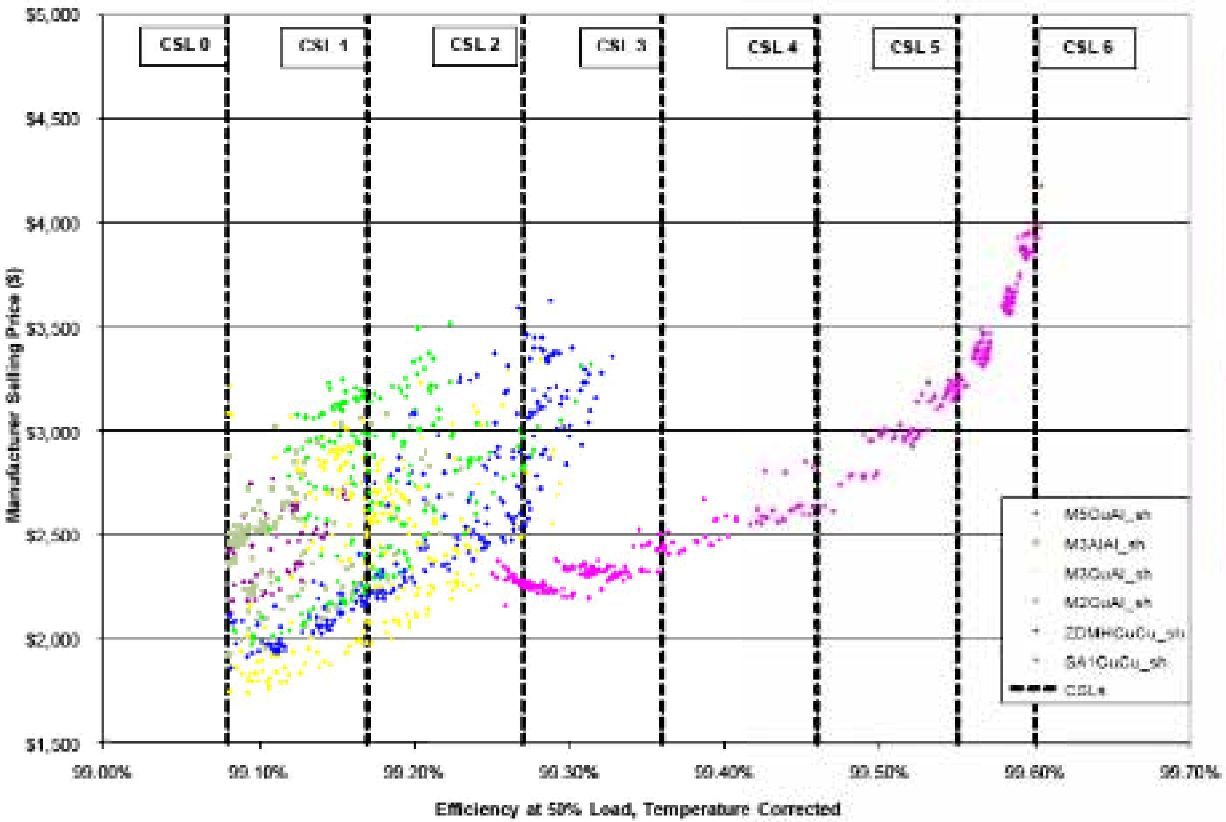


Figure 5.6.1 Engineering Analysis Results, Design Line 1

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

25 kVA 1Φ Pole Transformer Selling Price vs. CSL

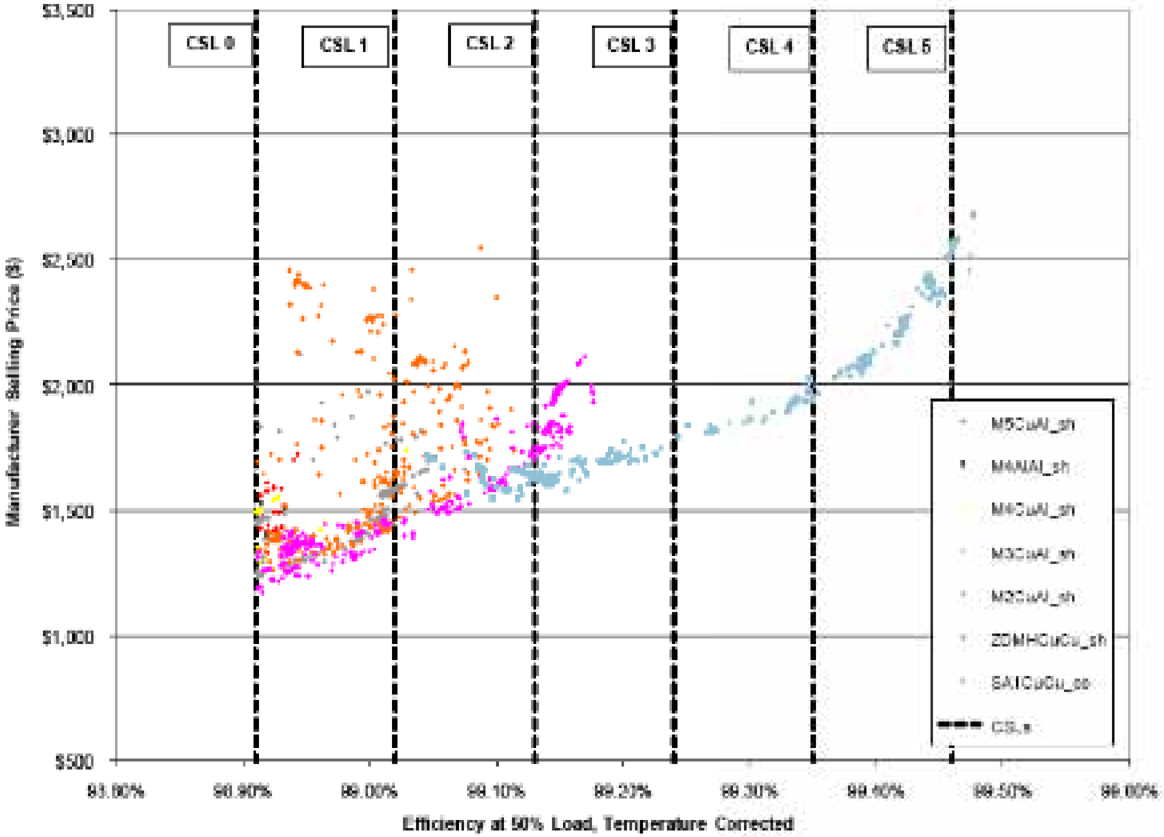


Figure 5.6.2 Engineering Analysis Results, Design Line 2

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

500 kVA 1Φ Pole Transformer Selling Price vs. CSL

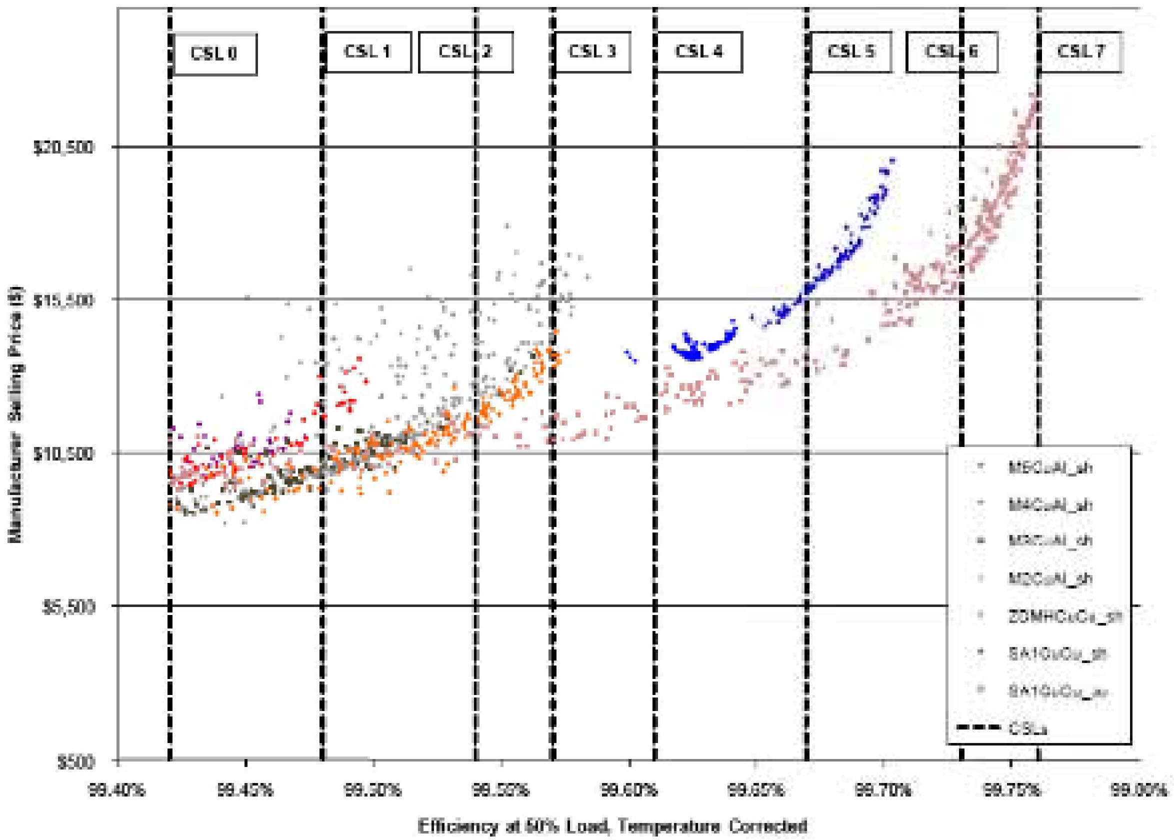


Figure 5.6.3 Engineering Analysis Results, Design Line 3

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

150 kVA 3Φ Pad Transformer Selling Price vs. CSL

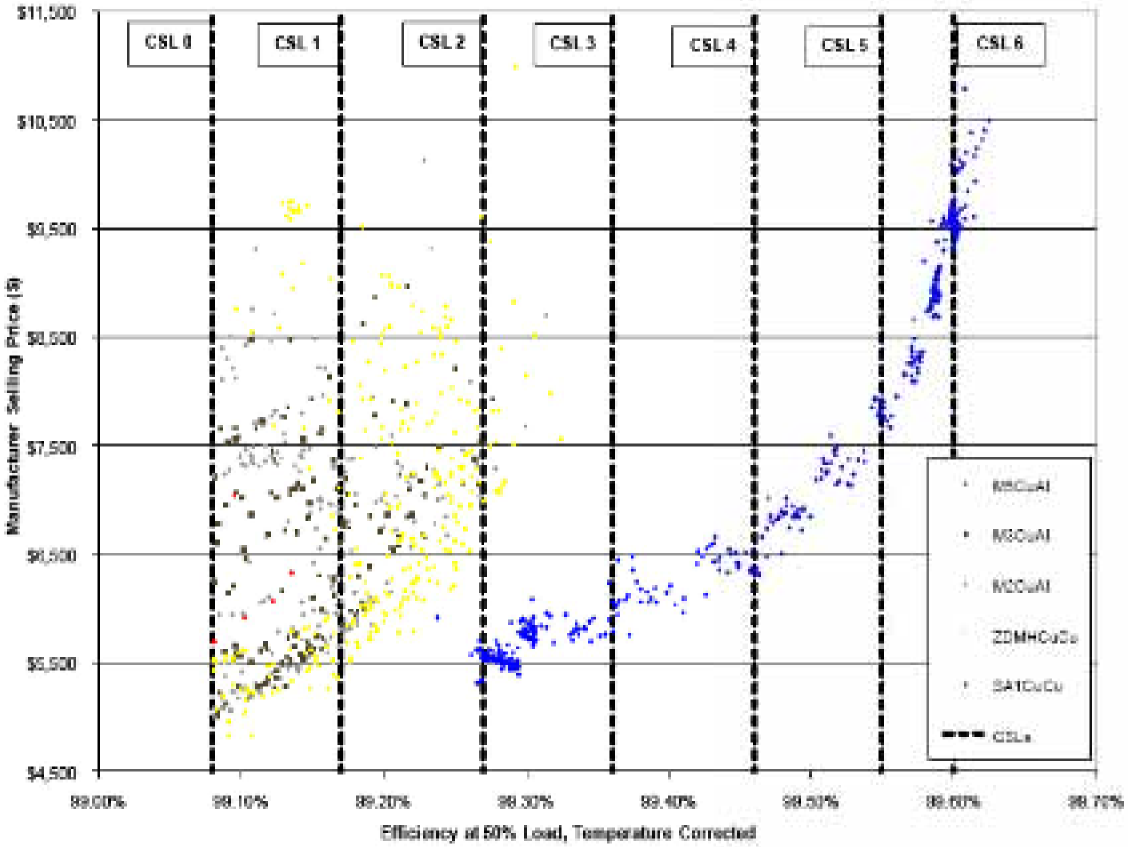


Figure 5.6.4 Engineering Analysis Results, Design Line 4

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

1500 kVA 3Φ Pad Transformer Selling Price vs. CSL

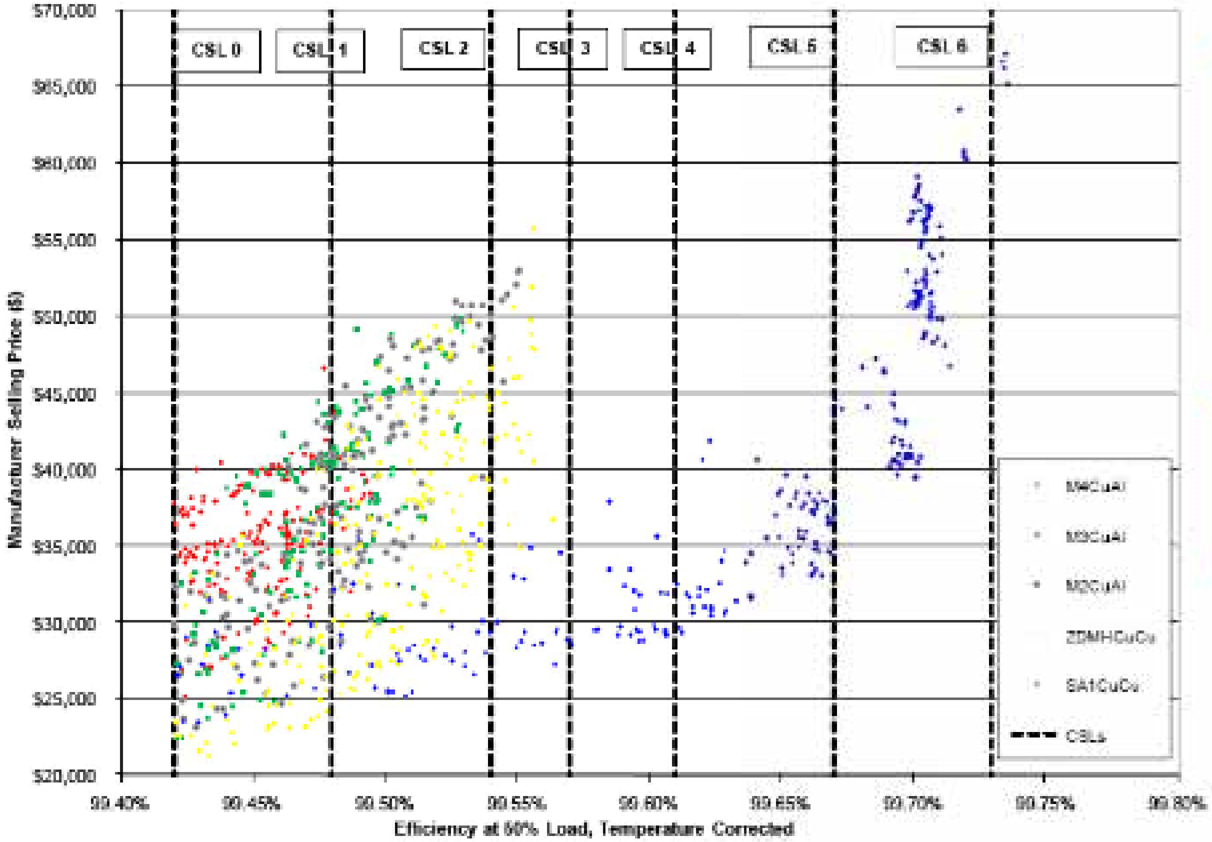


Figure 5.6.5 Engineering Analysis Results, Design Line 5

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

75 kVA 3Φ LV Dry Transformer Selling Price vs. CSL

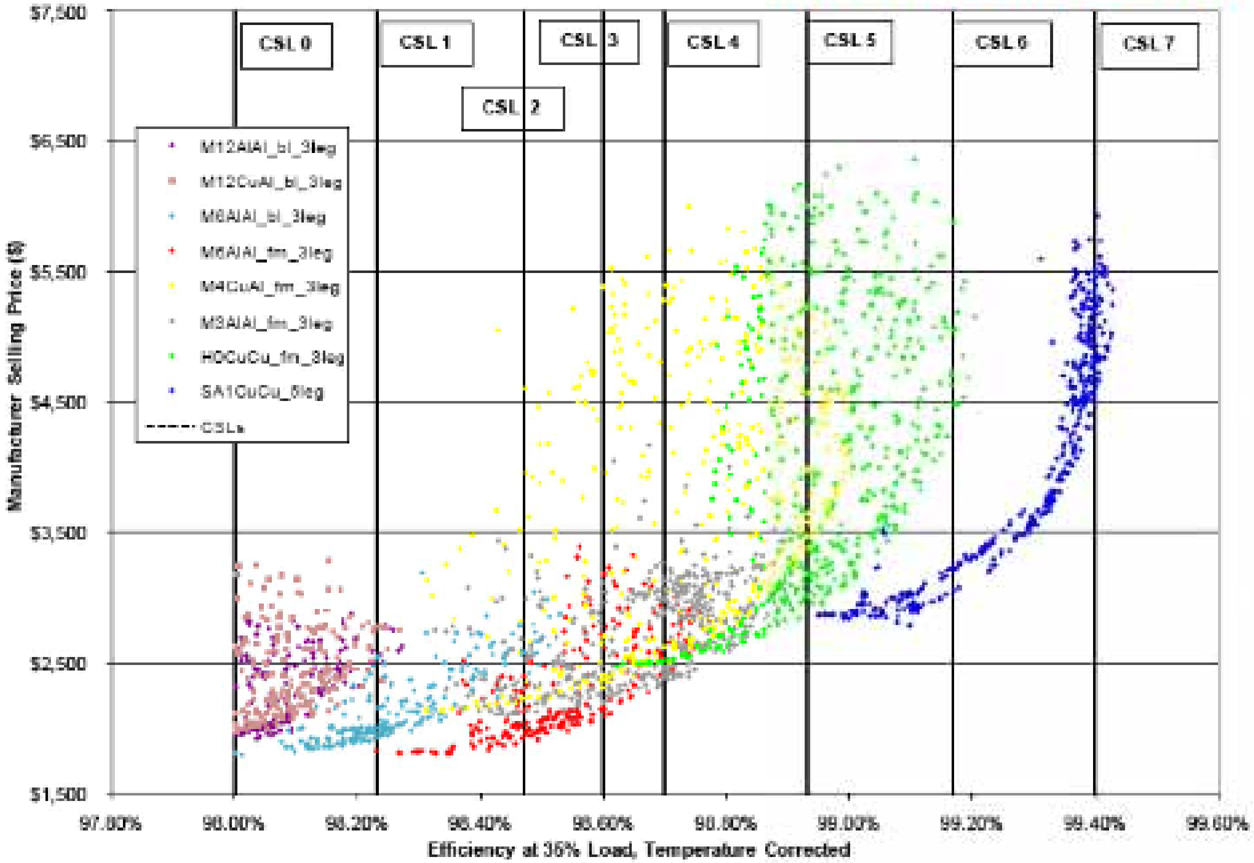


Figure 5.6.7 Engineering Analysis Results, Design Line 7

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

300 kVA 3Φ LV 10 kV BIL Dry Transformer Selling Price vs. CSL

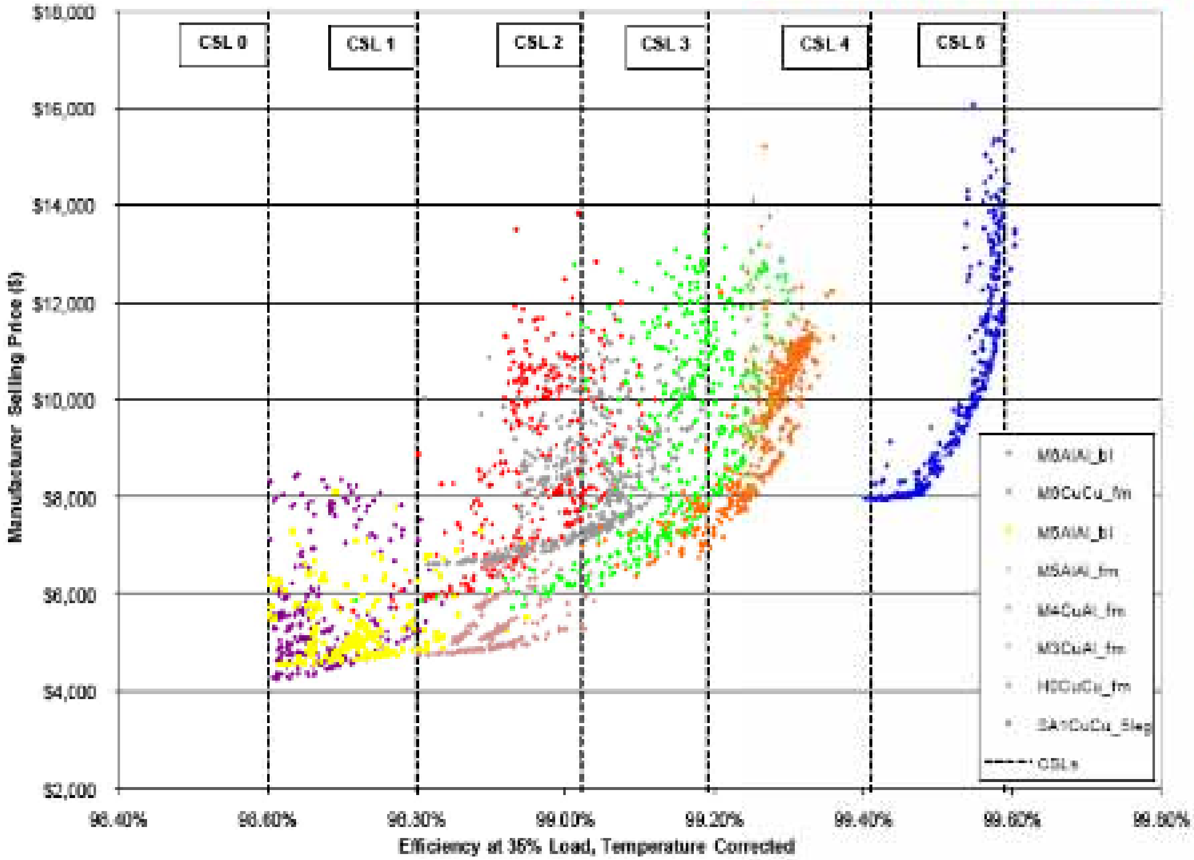


Figure 5.6.8 Engineering Analysis Results, Design Line 8

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

300 kVA 3Φ MV 45 kV BIL Dry Transformer Selling Price vs. CSL

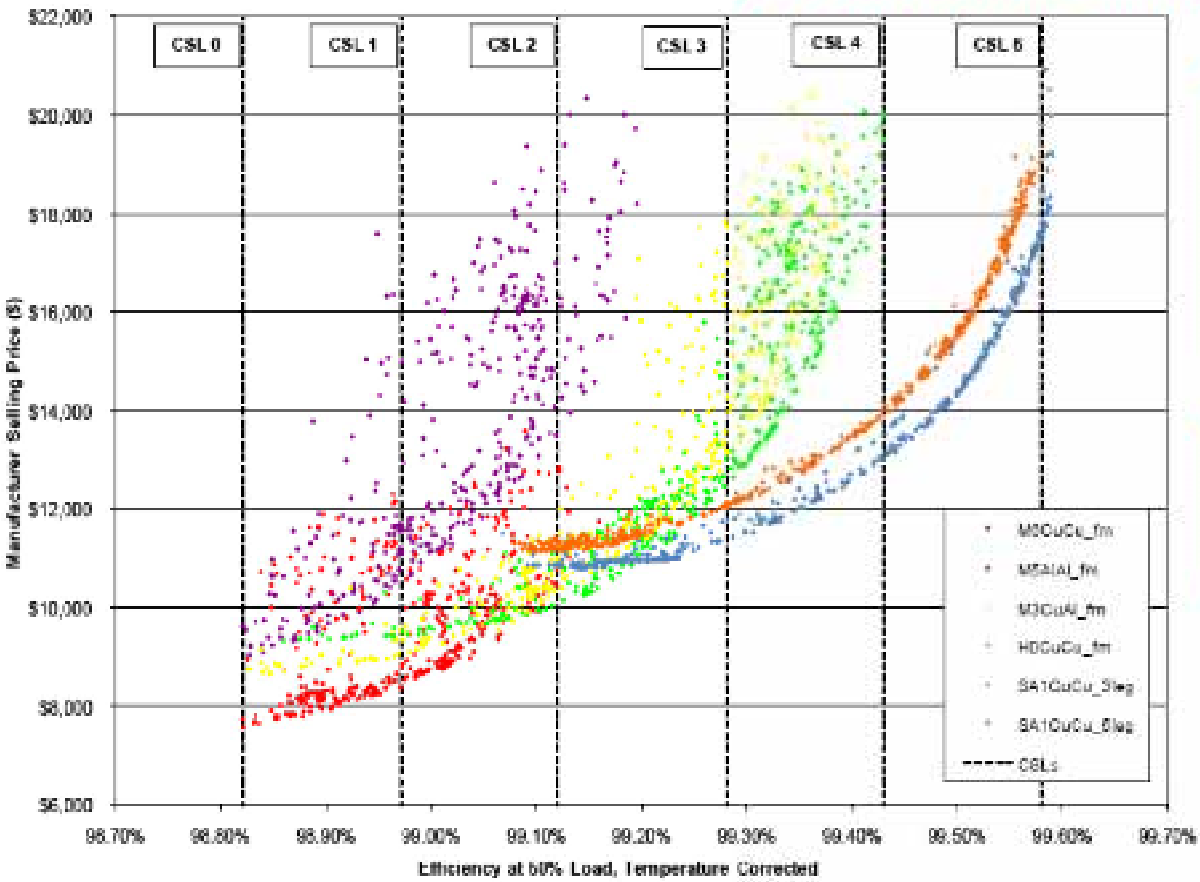


Figure 5.6.9 Engineering Analysis Results, Design Line 9

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1500 kVA 3Φ MV 45 kV BIL Dry Transformer Selling Price vs. CSL

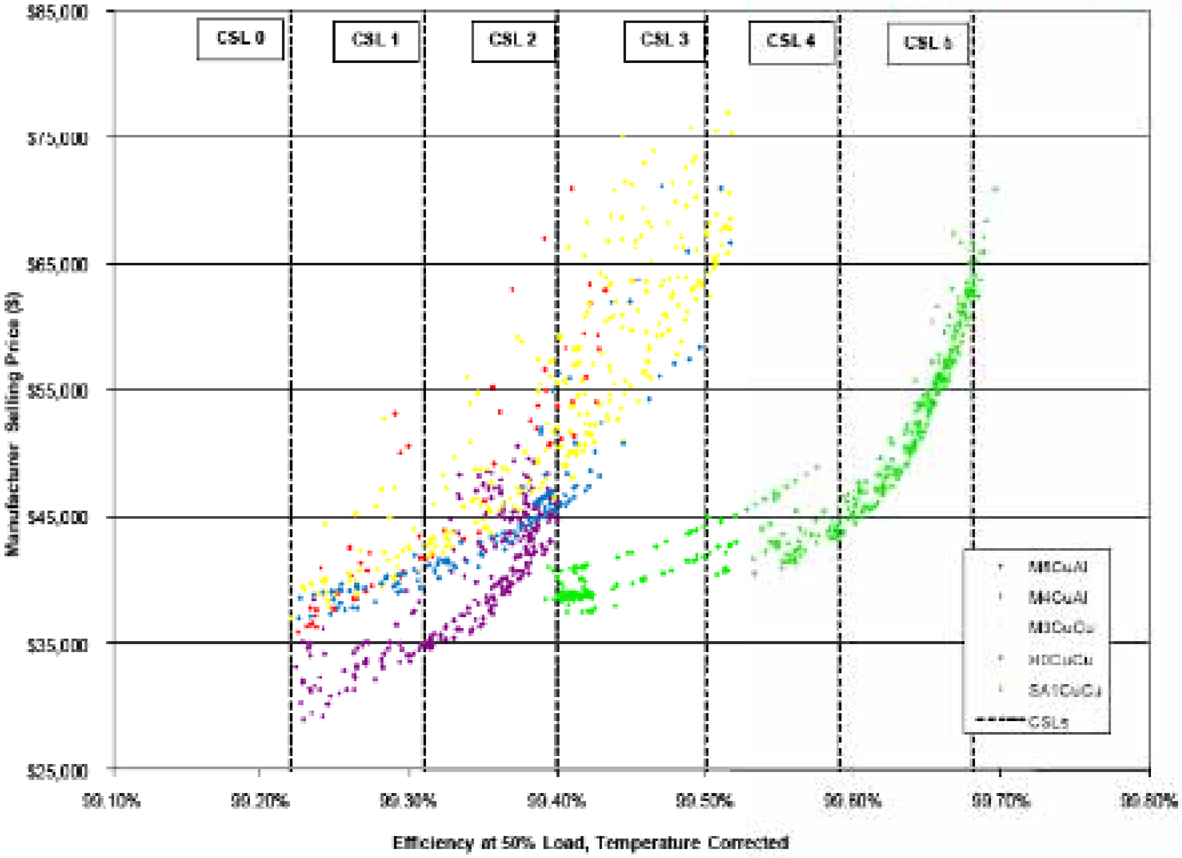


Figure 5.6.10 Engineering Analysis Results, Design Line 10

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

300 kVA 3Φ MV 95 kV BIL Dry Transformer Selling Price vs. CSL

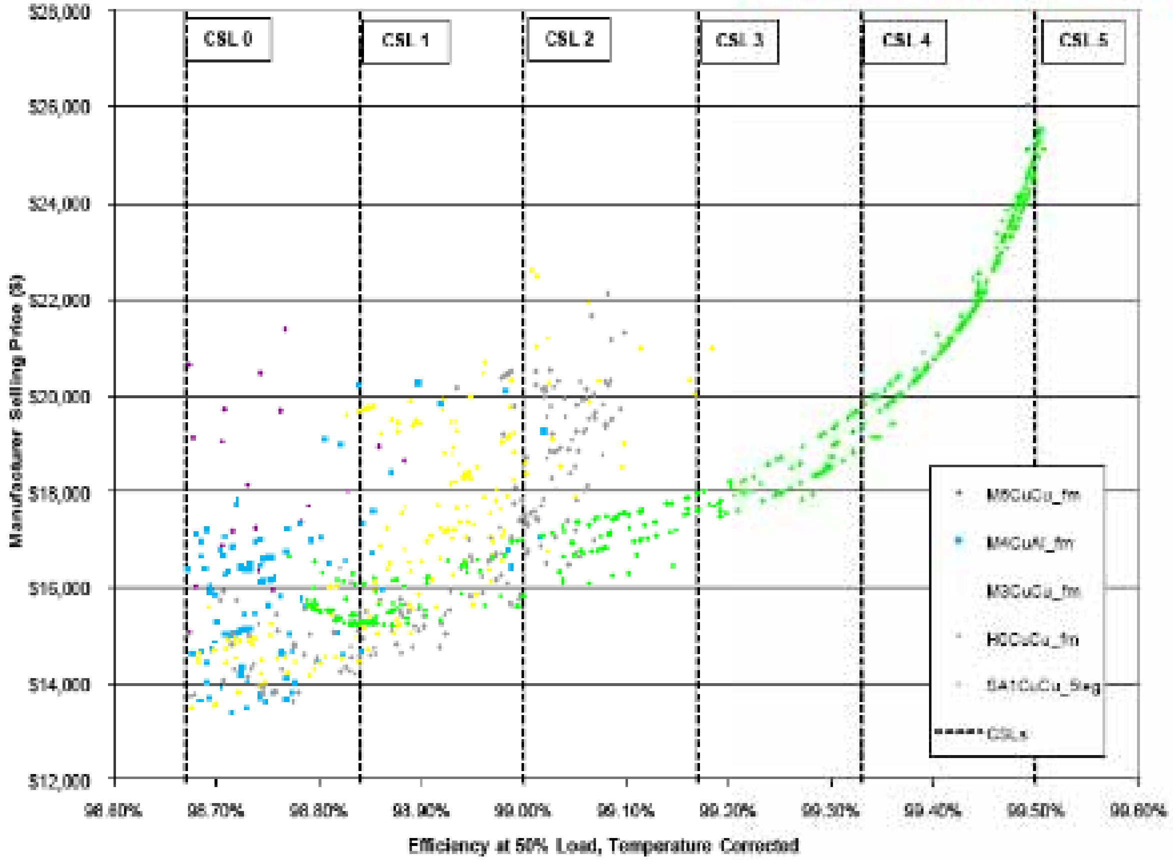


Figure 5.6.11 Engineering Analysis Results, Design Line 11

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

1500 kVA 3Φ MV 95 kV BIL Dry Transformer Selling Price vs. CSL

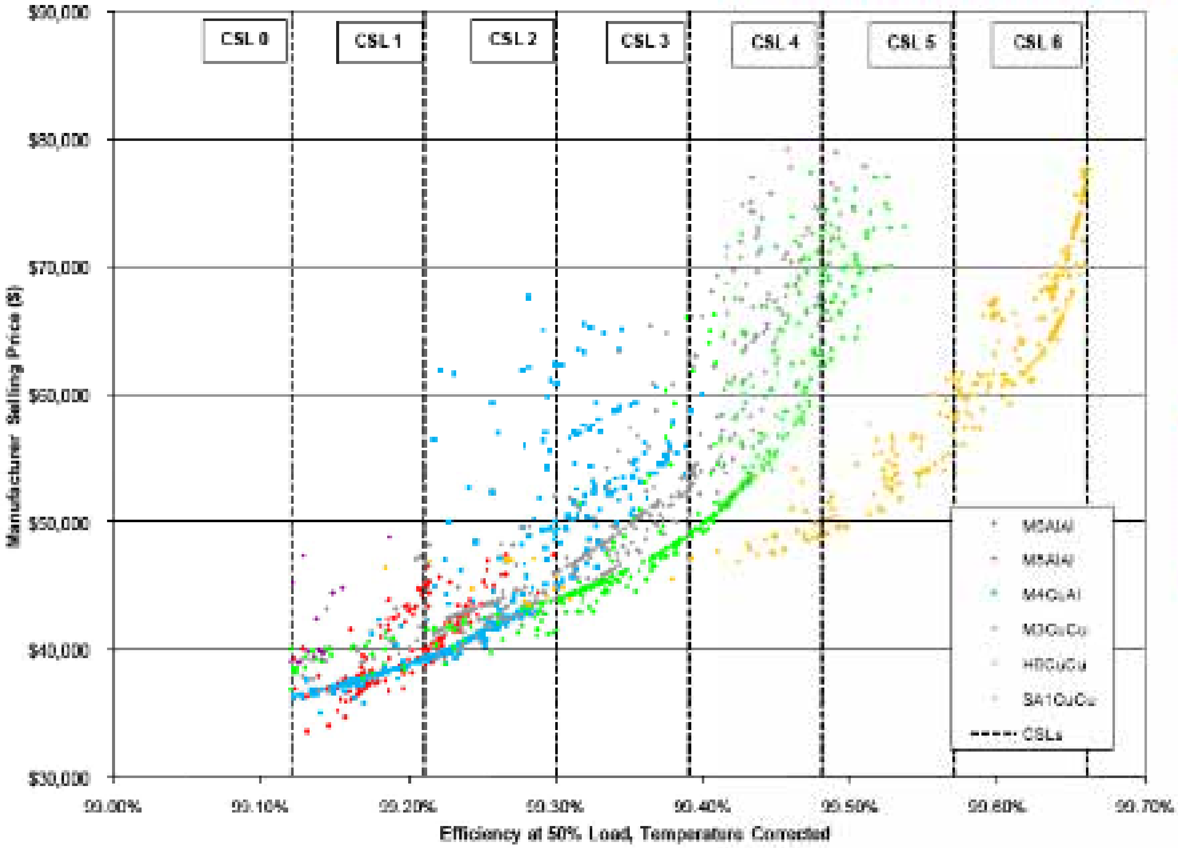


Figure 5.6.12 Engineering Analysis Results, Design Line 12

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

2000 kVA 3Φ MV 95 kV BIL Dry Transformer Selling Price vs. CSL

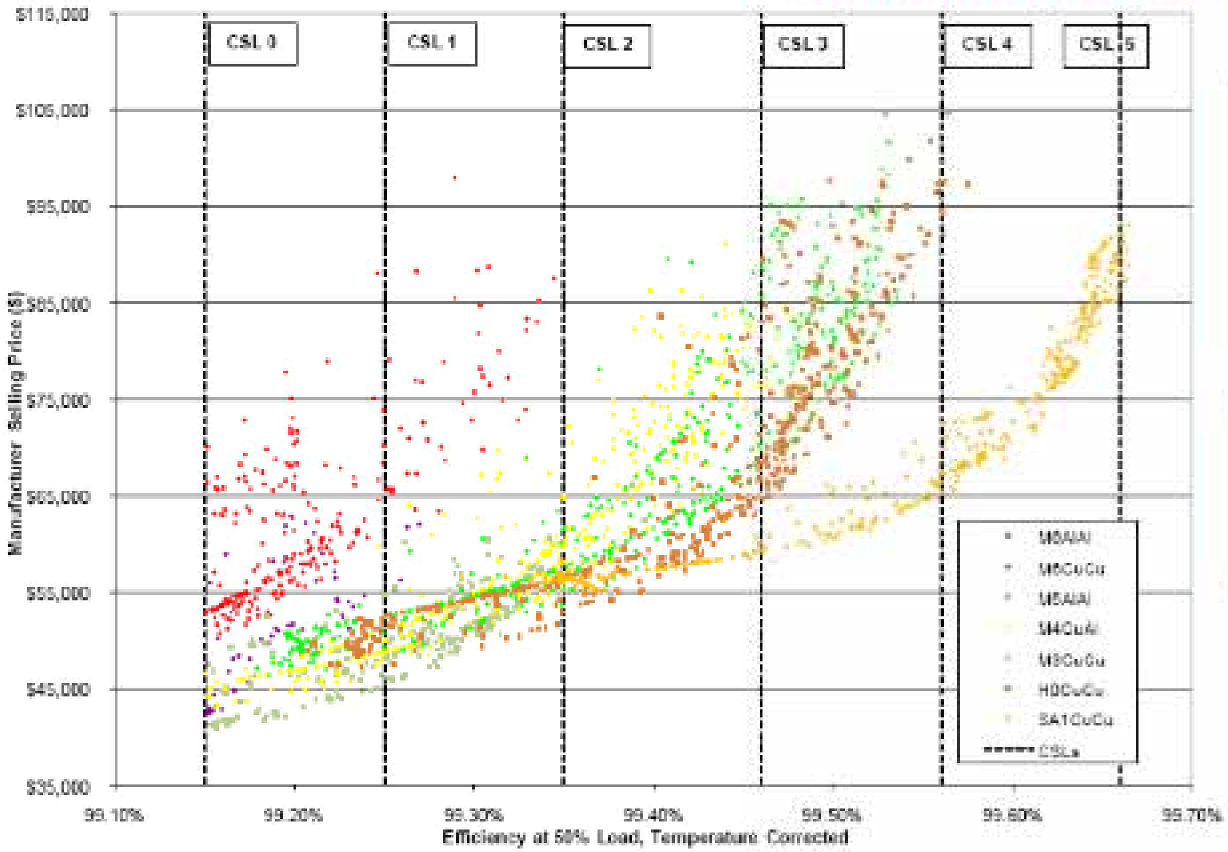


Figure 5.6.13 Engineering Analysis Results, Design Line 13

Base is the 2010 energy efficiency requirement

They may get a lot more expensive

Summary of Alternative CSL's

1. CSL0 is the existing standard
2. New considerations through CSL 3 are uniformly on steep cost curve.
3. Implication is for higher efficiency standards
4. DOE is reviewing assumptions and inputs to select new proposed CSL.

They may get a lot more expensive

Table 5.5.1 Summary of Baselines and Candidate Standard Levels for Distribution Transformer Representative Units

Design Line	Representative Unit	Baseline	CSL1	CSL2	CSL3	CSL4	CSL5	CSL6	CSL7	CSL8
		Eff. [%]	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*	*Eff. [%]*
1	50 kVA, 65°C, single-phase, 60Hz, 14400V primary, 240/120V secondary, rectangular tank	99.08	99.17	99.27	99.36	99.46	99.55	99.60	N/A	N/A
2	25 kVA, 65°C, single-phase, 60Hz, 14400V primary, 120/240V secondary, round tank	98.91	99.02	99.13	99.24	99.35	99.46	N/A	N/A	N/A
3	500 kVA, 65°C, single phase, 60Hz, 14400V primary, 277V secondary	99.42	99.48	99.54	99.57	99.61	99.67	99.73	99.76	N/A
4	150 kVA, 65°C, three-phase, 60Hz, 12470Y/7200V primary, 208Y/120V secondary	99.08	99.17	99.27	99.36	99.46	99.55	99.60	99.65	N/A
5	1500 kVA, 65°C, three-phase, 60Hz, 24940GrdY/14400V primary, 480Y/277V secondary	99.42	99.48	99.54	99.57	99.61	99.67	99.73	99.75	N/A
6	25 kVA, 150°C, single-phase, 60Hz, 480V primary, 120/240V secondary, 10kV BIL	98.00	98.23	98.47	98.60	98.70	98.93	99.17	99.40	N/A
7	75 kVA, 150°C, three-phase, 60Hz, 480V primary, 208Y/120V secondary, 10kV BIL	98.00	98.23	98.47	98.60	98.70	98.93	99.17	99.40	99.48
8	300 kVA, 150°C, three-phase, 60Hz, 480V Delta primary, 208Y/120V secondary, 10kV BIL	98.60	98.80	99.02	99.19	99.41	99.59	99.63	N/A	N/A
9	300 kVA, 150°C, three-phase, 60Hz, 4160V Delta primary, 480Y/277V secondary, 45kV BIL	98.82	98.97	99.12	99.28	99.43	99.58	99.62	N/A	N/A
10	1500 kVA, 150°C, three-phase, 60Hz, 4160V primary, 480Y/277V secondary, 45kV BIL	99.22	99.31	99.40	99.50	99.59	99.68	99.71	N/A	N/A
11	300 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 95kV BIL	98.67	98.84	99.00	99.17	99.33	99.50	99.55	N/A	N/A
12	1500 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 95kV BIL	99.12	99.21	99.30	99.39	99.48	99.57	99.66	99.69	N/A
13	2000 kVA, 150°C, three-phase, 60Hz, 12470V primary, 480Y/277V secondary, 125kV BIL	99.15	99.25	99.35	99.46	99.56	99.66	99.68	N/A	N/A

They may get a lot more expensive

Time for inputs from Industry

1. **What thoughts about existing levels?**
2. **How difficult is it to meet present standards?**
3. **What materials are now being used to meet existing standards?**
4. **What CSL can you reach without new materials?**
5. **What CSL can you reach with new affordable equipment?**
6. **Any comments on material prices?**
7. **How accurate do you believe the modeled selling prices are?**
8. **What is your proposal for new CSL?**

You need to get involved

Possible New Technology with Symmetrical Cores

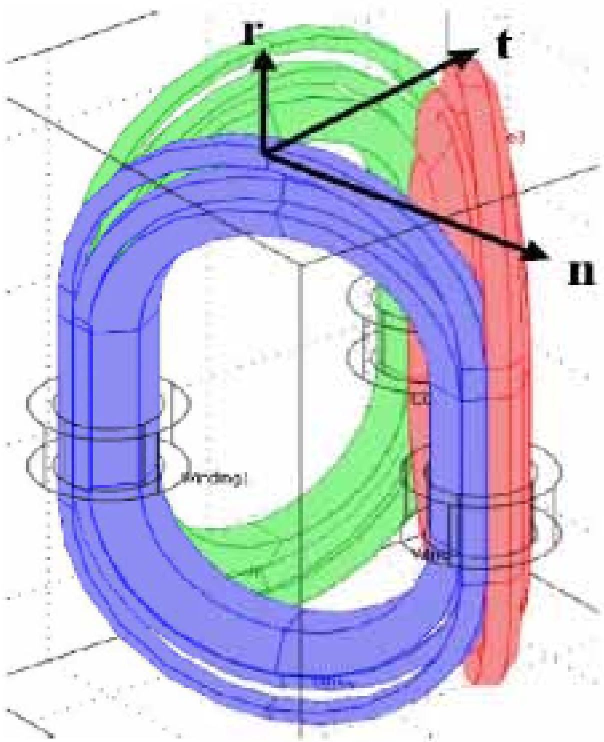
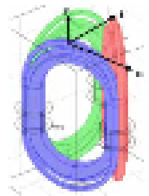


Figure 5.3.5 Graphic of Symmetric Core Configuration

Based on skewed wound cores



Possible New Technology with Symmetrical Cores for 3-phase applications

1. Practical usage limited to delta-Y configurations of low kVA like LV Dry
2. Y-Y configurations need 4th or 5th leg or delta winding
3. Utility transformers mostly Y-Y
4. Construction difficult to produce and requires new equipment

Limited range application

Possible New Technology with Deactivated Cores

Three 25 kVA transformers replace on 75 kVA transformer

Turn off what is not needed

Possible New Technology with Deacti

Three 25 kVA transformers replace on 75 kVA transformer

75 KVA load analys comparison for losses of (1) 75 kVA vs. combinations of 25 kVA's					
% Load	% Time	(1) 75 kVA total	1-25 kVA total	2-25 kVA total	3-25 kVA total
0	31	133	58	115	173
15	22	162	174	174	212
35	20	295	693	433	385
50	18	464	1354	764	605
76	9	878	2975	1574	1145

Only 0% load favors deactivated cores

New Regulations for Certifications in March 7, 2011 issue of 10 CFR 431.

1. Certification required by July 5, 2011.
2. Applies to production for next calendar year
3. Requires new certification each year.
4. Provides for spot checks by the DOE
5. Non-compliance can lead to shutdowns

Recommendations:

1. Use 5 models to characterize a product line
2. Use more than 5 samples to show compliance
3. Seek certification early
4. Be conservative!

Distribution Transformer Energy Efficiency Task Force
Philip J Hopkinson, PE

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
  - phopkinson@ieee.org
  - 704-846-3290
  - Sco.choinski@nema.org
  - 703-841-3253

DOE contact: Brenda Edwards Jones
1000 Independence Avenue, SW
Washington, DC 20585-0121

DistributionTransformers-2010-STD-0048@ee.doe.gov

Note minutes from April 12, 2011