Distribution Transformer Energy Efficiency Task Force

Philip J Hopkinson, PE

1. **Introduction**
2. **Minutes from Munich, 03/12/13**
3. **NOPR Issued By DOE**

http://www1.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers.html

1. **DOE DT Final Rule published April 18, 2013, Official June 17, 2013 and effective January 1, 2016**
2. **This is final meeting for task force**

Distribution Transformer Energy Efficiency Task Force

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Meeting Minutes from Milwaukee, October 23, 2012 Part 1 of 2

Distribution Transformer Subcommittee

Task force / Working Group Report

Document #:	n/a	Current Standard Date:	n/a
Document Title:	TF on DOE Transformer Efficiency Activity		
Chair:	Phil Hopkinson	Vice-Chair	
Secretary	Steve Griffith		
PAR Date:	n/a	PAR Expiration Date:	n/a
PAR Status:	n/a		
Current Draft Being Worked On:	n/a	Dated:	n/a
Meeting Date:	March 19, 2013	Time:	11:00 AM

Attendance:	Members	28
	Guests	29
	Guests Requesting Membership	13
	Total	70

Distribution Transformer Energy Efficiency Task Force

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Meeting Minutes from Milwaukee, October 23, 2012 Part 2 of 2

Meeting Minutes / Significant Issues / Comments:

The Task Force on DOE Energy Efficiency of Transformers was called to order at 1:45 PM on March 19, 2013. A hand count of the members was made and a quorum was declared. The chairman reviewed the minutes of the Fall 2012 meeting in Milwaukee and the minutes were approved. The chair recognized Al Traut as the acting secretary for this meeting.

The chair reported that the DOE has submitted a proposed Final Rule to the Office of Management and Budget (OMB) in November 2012. To date the OMB has not acted on the proposal. There is no known timeframe for OMB to complete their review.

The chair reviewed the slides that outline the results of the DOE process. The DOE issued a NOPR on Feb 10, 2012 (see 77FR7282). In this NOPR it recommended efficiency increases on medium voltage liquid immersed, medium voltage dry type, and low voltage dry type transformers. The last public meeting on the NOPR was held in June 2012. The details of the NOPR and the interpretation presented can be found on the IEEE Transformer Committee website. This content has not changed since the Fall 2012 meeting.

There were some comments that the OMB is meeting with select groups on a confidential basis to solicit input regarding the DOE proposed Final Rule. These groups include representatives of utilities, eg, EEI; manufactures, eg, NEMA; and core steel producers. While details are not available it is a hopeful sign that the OMB is actively evaluating the proposed rule.

There was discussion around the energy efficiency standard activity in other countries, eg, Europe and Australia. In these cases there appears to be more interest on power transformers than distribution transformers. This work is not available to the public at this time.

The meeting was adjourned at 3:00 PM

Submitted By:	**Al Traut**
Date:	**March 19, 2013**

DOE Link posted April 18, 2013:

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/66

Note

Distribution Transformers

Sign up for e-mail updates on regulations for this and other products

A distribution transformer provides the final voltage transformation in the electric power distribution system by reducing the high voltage of electric current from a power line to a lower voltage for use in a building. The Department of Energy (DOE) has regulated the energy efficiency level of low-voltage dry-type distribution transformers since 2007, and liquid-immersed and medium-voltage dry-type distribution transformers since 2010. A distribution transformer designed and constructed to be mounted on a utility pole is referred to as a pole-mount transformer. A distribution transformer designed and constructed to be located at ground level or underground, mounted on a concrete pad, and locked in a steel case is referred to as a pad-mount transformer.

Beginning in 2016, newly amended energy efficiency standards for distribution transformers will save up to $12.9 billion in total costs to consumers — ultimately saving families and businesses money while also reducing energy consumption. The new distribution transformer standards will also save 3.63 quadrillion British thermal units of energy for equipment sold over the 30-year period of 2016 to 2045.

The new amendments to the existing efficiency standards would further decrease electrical losses by about 8 percent for liquid-immersed transformers, 13 percent for medium-voltage dry-type transformers, and 18 percent for low-voltage dry-type transformers. In addition, about 264.7 million metric tons of carbon dioxide emissions will be avoided, equivalent to the annual greenhouse gas emissions of about 51.75 million automobiles.

The distribution transformers final rule was the DOE's first "negotiated rulemaking," conducted under the Federal Advisory Committee Act and the Negotiated Rulemaking Act, and is viewed as an alternative to traditional procedures for drafting proposed regulations.

The Standards and Test Procedures for this product are related to Rulemaking for Liquid-Immersed and Medium-Voltage Dry-type Distribution Transformers Energy Conservation Standard and Rulemaking for Low-Voltage Dry-Type Distribution Transformers Energy Conservation Standard.

Recent Updates | Standards | Test Procedures | Waiver, Exception, and Exemption Information | Statutory Authority | Historical Information | Contact Information

Recent Updates

DOE published a final rule regarding amended energy efficiency standards for liquid-immersed, medium-voltage dry-type, and low-voltage dry-type distribution transformers. 78 FR 23335 (April 18, 2013). For more information, please see the rulemaking webpages: liquid-immersed and medium-Voltage Dry-type and low-voltage dry-type.

1. Final Rule

Table I.1. Energy Conservation Standards for Liquid-Immersed Distribution Transformers (Compliance Starting January 1, 2016)

Equipment Classes	Design Line	Type	Phase Count	BIL*	Adopted TSL
1	1, 2 and 3	Liquid-immersed	1	All	1
2	4 and 5	Liquid-immersed	3	All	1

* BIL means "basic impulse insulation level" and measures how resistant a transformer's insulation is to large voltage transients.

Table I.2. Energy Conservation Standards for Low-Voltage Dry-Type Distribution Transformers (Compliance Starting January 1, 2016)

Equipment Class	Design Line	Type	Phase Count	BIL*	Adopted TSL
3	6	Low-voltage dry-type	1	≤ 10 kV	2
4	7 and 8	Low-voltage dry-type	3	≤ 10 kV	2

* BIL means "basic impulse insulation level" and measures how resistant a transformer's insulation is to large voltage transients.

Table I.3. Energy Conservation Standards for Medium-Voltage Dry-Type Distribution Transformers (Compliance Starting January 1, 2016)

Equipment Class	Design Line	Type	Phase Count	BIL*	Adopted TSL
5	9 and 10	Medium-voltage dry-type	1	25-45 kV	2
6	9 and 10	Medium-voltage dry-type	3	25-45 kV	2
7	11 and 12	Medium-voltage dry-type	1	46-95 kV	2
8	11 and 12	Medium-voltage dry-type	3	46-95 kV	2
9	13A and 13B	Medium-voltage dry-type	1	≥96 kV	2
10	13A and 13B	Medium-voltage dry-type	3	≥96 kV	2

* BIL means "basic impulse insulation level" and measures how resistant a transformer's insulation is to large voltage transients.

2. Definitions in Final Rule

Table I.4. Trial Standard Level to Energy Efficiency Level Mapping for Distribution Transformer Energy Conservation Standards

Type	Design Line	Phase Count	TSL	Energy Efficiency Level	Efficiency (%)
Liquid-immersed	1	1	1	1 (0.4 actual)*	99.11
	2	1		Base (0.5 actual)*	98.95
	3	1		1 (1.1 actual)*	99.49
	4	3		1	99.16
	5	3		1	99.48
Low-voltage dry-type	6	1	2	Base	98.00
	7	3		3	98.60
	8	3		2	99.02
Medium-voltage dry-type	9	3	2	1	98.93
	10	3		2	99.37
	11	3		1	98.81
	12	3		2	99.30
	13A	3		1	98.69
	13B	3		2	99.28

* Because of scaling, actual efficiency values unavoidably differ from nominal EL values.

- **TSL not the same as EL**
- **Base efficiency is Present DOE Mandatory Efficiencies**

3. Liquid Filled Final Rule

Table I.5 Electrical Efficiencies for All Liquid-Immersed Distribution Transformer Equipment Classes (Compliance Starting January 1, 2016)

Standards by kVA and Equipment Class			
Equipment Class 1		Equipment Class 2	
kVA	%	kVA	%
10	98.70	15	98.65
15	98.82	30	98.83
25	98.95	45	98.92
37.5	99.05	75	99.03
50	99.11	112.5	99.11
75	99.19	150	99.16
100	99.25	225	99.23
167	99.33	300	99.27
250	99.39	500	99.35
333	99.43	750	99.40
500	99.49	1,000	99.43
667	99.52	1,500	99.48
833	99.55	2,000	99.51
		2,500	99.53

1 Phase separated from 3 Phase with losses reduced by 2.6-12.1%
3 Phase Losses reduced by 5.2-17.7%

4. Low Voltage Dry Final Rule

Table I.6 Electrical Efficiencies for All Low-Voltage Dry-Type Distribution Transformer Equipment Classes (Compliance Starting January 1, 2016)

Standards by kVA and Equipment Class			
Equipment Class 3		Equipment Class4	
kVA	%	kVA	%
15	97.70	15	97.89
25	98.00	30	98.23
37.5	98.20	45	98.40
50	98.30	75	98.60
75	98.50	112.5	98.74
100	98.60	150	98.83
167	98.70	225	98.94
250	98.80	300	99.02
333	98.90	500	99.14
		750	99.23
		1,000	99.28

3 Phase % reduction

29.7
29.2
30.4

30.0
30.0
31.2

29.3
30.0
33.8

35.8
34.5

- **1 Phase remains at Base**
- **3 Phase losses reduced by 29-36%**
- **These reductions will have large impacts on the Industry!**

Distribution Transformer Energy Efficiency Task Force

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5. Medium Voltage Dry Final Rule

Table I.7 Electrical Efficiencies for All Medium-Voltage Dry-Type Distribution Transformer Equipment Classes (Compliance Starting January 1, 2016)

Standards by kVA and Equipment Class											
Equipment Class 5		Equipment Class 6		Equipment Class 7		Equipment Class 8		Equipment Class 9		Equipment Class 10	
kVA	%	kVA	%	kVA	%	kVA	%	kVA	%	kVA	%
15	98.10	15	97.50	15	97.86	15	97.18				
25	98.33	30	97.90	25	98.12	30	97.63				
37.5	98.49	45	98.10	37.5	98.30	45	97.86				
50	98.60	75	98.33	50	98.42	75	98.13				
75	98.73	112.5	98.52	75	98.57	112.5	98.36	75	98.53		
100	98.82	150	98.65	100	98.67	150	98.51	100	98.63		
167	98.96	225	98.82	167	98.83	225	98.69	167	98.80	225	98.57
250	99.07	300	98.93	250	98.95	300	98.81	250	98.91	300	98.69
333	99.14	500	99.09	333	99.03	500	98.99	333	98.99	500	98.89
500	99.22	750	99.21	500	99.12	750	99.12	500	99.09	750	99.02
667	99.27	1,000	99.28	667	99.18	1,000	99.20	667	99.15	1,000	99.11
833	99.31	1,500	99.37	833	99.23	1,500	99.30	833	99.20	1,500	99.21
		2,000	99.43			2,000	99.36			2,000	99.28
		2,500	99.47			2,500	99.41			2,500	99.33

1 Phase remains at Base
3 Phase losses reduced by 0-23.5%

6. LCC and Paybacks in Final Rule

Table I.8 Impacts of Today's Standards on Customers of Distribution Transformers

Design Line	Average LCC Savings <u>2011$</u>	Median Payback Period <u>years</u>
Liquid-Immersed		
1	72	18.2
2	66	5.9
3	2,753	8.6
4	967	7.0
5	4,289	6.3
Low-voltage dry-type**		
6	N/A*	N/A*
7	1,678	3.6
8	2,588	7.7
Medium-voltage dry-type		
9	787	2.6
10	4,455	8.6
11	996	10.6
12	6,790	8.5
13A	-27	16.1
13B	4,346	12.2

*No customers are impacted by today's standard because there is no change from the minimum efficiency standard for design line 6.
** See section IV.A.3.d for discussion of core construction technique.

DOE Paybacks questionable due to energy cost, selling prices, and cost of funds

7. Assumptions

Table I.9 Summary of National Economic Benefits and Costs of Distribution Transformer Energy Conservation Standards

Category	Present Value Billion 2011$	Discount Rate %
Benefits		
Operating Cost Savings	6.30	7
	18.2	3
CO_2 reduction monetized value ($4.9/t case)*	0.80	5
CO_2 reduction monetized value ($22.3/t case)*	4.38	3
CO_2 reduction monetized value ($36.5/t case)*	7.51	2.5
CO_2 reduction monetized value ($67.6/t case)*	13.31	3
NO_X reduction monetized value ($2,591/ton)**	0.09	7
	0.23	3
Total benefits†	10.77	7
	22.8	3
Costs		
Incremental installed costs	2.89	7
	5.22	3
Net Benefits		
Including CO_2 and NO_X reduction monetized value	7.88	7
	17.6	3

* The CO_2 values represent global monetized values of the SCC in 2011$ in 2011 under several scenarios. The values of $4.9, $22.3, and $36.5/per metric ton (t) are the averages of SCC distributions calculated using 5%, 3%, and 2.5% discount rates, respectively. The value of $67.6/t represents the 95th percentile of the SCC distribution calculated using a 3% discount rate. The SCC time series used by DOE incorporate an escalation factor.

** The value represents the average of the low and high NO_X values used in DOE's analysis.

† Total benefits for both the 3% and 7% cases are derived using the series corresponding to SCC value of $22.3/t.

The Benefits and costs assumptions in the Final Rule

7. Considerations in Final Rule

a. Material prices supposed to reflect 2010-2011
b. Energy prices that are considerably higher than today's actuals.
c. Loading remains at 35% for LV and 50% for Medium Voltage
d. OPS designs that are sufficiently corrected from early errors
e. M3 core material and Amorphous
f. Transformer Selling price versus efficiency
g. Dollars cost per watt saved analysis
h. Energy savings versus efficiency levels
i. Payback period versus efficiency
j. Manufacturing Impact
k. Market Impact
l. Core Steel impacts
m. Proposed efficiencies.

1. All sides wanted M3 Core Material to remain Viable
2. Utilities worried about selling price increases
3. Considerable concern about rebuild market

8. Cautions by Utilities, Manufacturers, and Core Steel Makers in Final Rule

a. **Liquid filled single phase pads hit brick wall for efficiencies > EL1.**
b. **Liquid filled single phase poles already at brick wall with EL0.**
c. **Concerns expressed that M3 disappears with hard turn> EL1.**
d. **Medium Voltage Dry with mitered cores hits brick wall between EL2 and EL3.**
e. **LV Dry beyond EL1 must change to miter core or wound cores.**
f. **Small manufacturers may get squeezed out!**

- **Hi level letters written by NEMA and Steel Companies**
- **Multiple analyses submitted by several manufacturers**
- **Excellent analysis by Core Steel Makers**
- **Analysis submitted by Hopkinson**
- **Reality of M3 / Amorphous crossover may have been most convincing**

8. M3 and Amorphous cross over at Efficiency Level 1

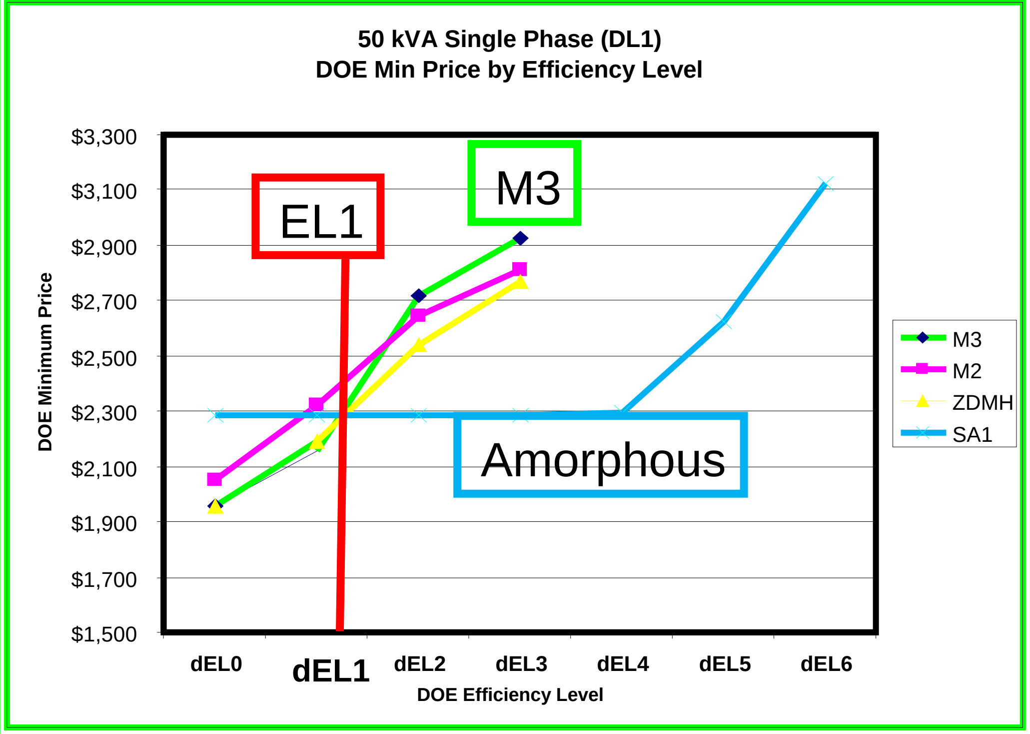

Chart Courtesy of Carlos Gaytan Based on 50 kVA single Phase Pad

Similar cost relationship for many manufacturers

- **M3, M2, and Hi B cost curves steep**
- **Amorphous cost curve flat**
- **Amorphous curve crosses M3 curve at EL1**
- **M3 not viable for efficiency > EL1**

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Design Line 12 Engineering

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

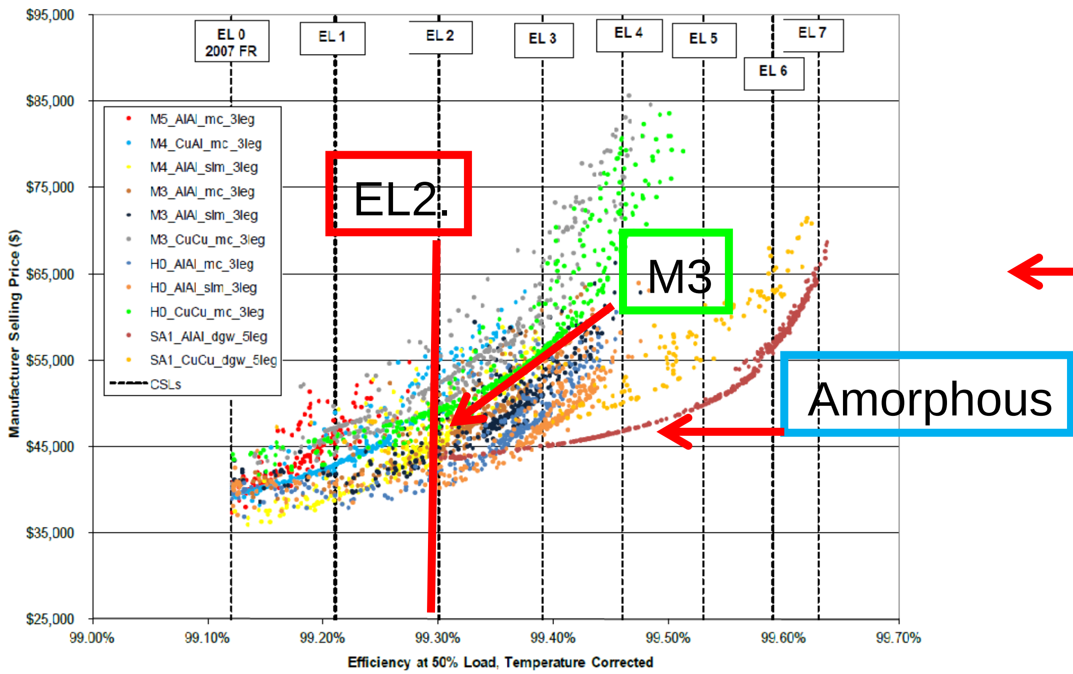

Chart Courtesy of LBL
Based on 1500 kVA Three Phase MV Dry

Similar cost relationship for many manufacturers

- **M3, M2, and Hi B cost curves steep**
- **Amorphous cost curve flat**
- **Amorphous curve crosses M3 curve at EL1**
- **M3 not viable for efficiency > EL2**

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Key Issues to establishing New Standards

1. **Transformer RMS Equivalent Load proposed to remain unchanged**
   a. Currently 35% for LV
   b. Currently 50% for MV
2. **Present worth value of a watt saved in 30 years with 3% inflation and 7% cost of money**
   a. Worth may be $6.71 for Utilities
   b. Worth probably < $9.91 for Industrials and Commercials as 30 years horizon believed excessive by manufacturers and users
3. **Core materials to be the basis of a minimum national standard**
   a. **M3 believed to be limit by manufacturers and domestic steel makers**
   b. Amorphous pushed by Conservation advocates
4. **Transformer selling price versus efficiency**
   a. OPS data questioned by LV and MV manufacturers
   b. Cost data some issues on materials costs.

References of Value

1. **DOE Materials**
   a. August 31, 2011 issued documents
   b. March 2011 documents
   c. Updated February, 2012
2. **Studies by Carlos Gaytan, Wes Patterson, and Phil Hopkinson**
   a. M3 based designs have steep cost curve versus efficiency
   b. The cost /watts saved for each makes higher efficiency look costly
   c. Amorphous cost curve much flatter versus efficiency
3. **AK Steel Global steel report**
   a. M3 believed as far as domestics can support
   b. ZDMH not available in the US
   c. Amorphous not adequately available to support 100% of DT's
4. **Reports by Utilities, Amorphous makers, users including field failures**
   a. Loading examined
   b. Field failures analyzed.

DOE Material Cost Reference for Liquid Filled Transformers

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

Material	Units	2010 Price *2010$*	Min. Price (2006 – 25%) *2010$*	Max. Price (2008 + 25%) *2010$*	2010 *2010$*	2009 *2010$*	2008 *2010$*	2007 *2010$*	2006 *2010$*
M6 core steel	*$/lb*	$ 1.46	$ 0.94	$ 2.19	$ 1.46	$ 1.64	$ 1.75	$ 1.58	$ 1.26
M5 core steel	*$/lb*	$ 1.51	$ 0.99	$ 2.24	$ 1.51	$ 1.67	$ 1.79	$ 1.61	$ 1.32
M4 core steel	*$/lb*	$ 1.59	$ 1.03	$ 2.30	$ 1.59	$ 1.70	$ 1.84	$ 1.64	$ 1.38
M3 core steel	*$/lb*	$ 1.88	$ 1.06	$ 2.60	$ 1.88	$ 1.96	$ 2.08	$ 1.70	$ 1.41
M3 core steel (Lite Carlite)	*$/lb*	$ 1.95	$ 1.47	$ 2.44	$ 1.95	$ -	$ -	$ -	$ -
M2 core steel	*$/lb*	$ 2.00	$ 1.32	$ 2.79	$ 2.00	$ 2.01	$ 2.23	$ 2.18	$ 1.76
M2 core steel (Lite Carlite)	*$/lb*	$ 2.10	$ 1.58	$ 2.63	$ 2.10	$ -	$ -	$ -	$ -
ZDMH (mechanically-scribed core steel)	*$/lb*	$ 2.05	$ 1.41	$ 3.22	$ 2.05	$ 2.02	$ 2.57	$ 2.29	$ 1.88
SA1 (amorphous) finished core, volume production	*$/lb*	$ 2.38	$ 1.72	$ 3.64	$ 2.38	$ 2.29	$ 2.91	$ -	$ -
Copper wire, formvar, round #10-20	*$/lb*	$ 4.87	$ 3.33	$ 5.97	$ 4.87	$ 3.81	$ 4.77	$ 4.78	$ 4.44
Copper wire, enameled, round #7-10	*$/lb*	$ 4.84	$ 3.31	$ 5.93	$ 4.84	$ 3.78	$ 4.74	$ 4.75	$ 4.41
Copper wire, enameled, rectangular sizes	*$/lb*	$ 4.97	$ 3.41	$ 6.09	$ 4.97	$ 3.91	$ 4.87	$ 4.88	$ 4.54
Aluminum wire, formvar, round #9-17	*$/lb*	$ 3.07	$ 2.30	$ 3.91	$ 3.07	$ 3.00	$ 3.13	$ 3.08	$ 3.07
Aluminum wire, formvar, round #7-10	*$/lb*	$ 2.57	$ 1.93	$ 3.28	$ 2.57	$ 2.50	$ 2.63	$ 2.58	$ 2.57
Copper strip, thickness range 0.02-0.045	*$/lb*	$ 4.97	$ 3.41	$ 6.09	$ 4.97	$ 3.91	$ 4.87	$ 4.88	$ 4.54
Copper strip, thickness range 0.030-0.060	*$/lb*	$ 4.97	$ 3.41	$ 6.09	$ 4.97	$ 3.91	$ 4.87	$ 4.88	$ 4.54
Aluminum strip, thickness range 0.02-0.045	*$/lb*	$ 2.08	$ 1.56	$ 2.67	$ 2.08	$ 2.01	$ 2.14	$ 2.09	$ 2.08
Aluminum strip, thickness range 0.045-0.080	*$/lb*	$ 2.08	$ 1.56	$ 2.67	$ 2.08	$ 2.01	$ 2.14	$ 2.09	$ 2.08
Kraft insulating paper with diamond adhesive	*$/lb*	$ 1.52	$ 1.17	$ 1.93	$ 1.52	$ 1.54	$ 1.54	$ 1.56	$ 1.56
Mineral oil	*$/gal*	$ 3.35	$ 1.94	$ 3.84	$ 3.35	$ 2.89	$ 3.07	$ 2.51	$ 2.59
Tank Steel	*$/lb*	$ 0.38	$ 0.32	$ 0.60	$ 0.38	$ 0.39	$ 0.48	$ 0.43	$ 0.43

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This is the last meeting of the Task Force

1. **There is continued activity on Energy Efficiency for Transformers in IEC TC 14.**
2. **At this point in time there is no further activity on transformers by the DOE**
3. **If new DOE work is announced then the Task Force could be reactivated.**
4. **Thanks all for support and guidance.**