MTC

Metals Technology Consulting, Inc.

Presentation to the

US Department of Energy

In response to a request for public comments

regarding

Proposed New Standards for Energy Efficiency of Distribution Transformers

On behalf of

Metals Technology Consulting, Inc
and
The Core Coalition, LLC

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1.0 Introduction

The Department of Energy (DOE) has requested public comments (Federal Register Vol. 88, No. 7/Wednesday January 11, 2023, 10 CFR Part 431, [EERE-2019-BT-STD-0018], RIN 1904-AE12) regarding proposed new energy efficiency standards for distribution transformers.

Metals Technology Consulting (MTC) is a consulting firm specializing in all aspects of the global and domestic electrical steel industries, both Non-Oriented (NOES) and Grain Oriented (GOES), including:

- Production and capacity
- Technology and properties
- Consumption and Trade related data
- Market Analysis
- Applications
- Strategic Analysis

MTC is a co-founder (together with Steel-Insights LLC) of The Core Coalition, a strategic alliance of electrical steel manufacturers, transformer core manufactures, and transformer manufacturers. We delivered submissions to the Department of Commerce in 2020 in response to its request for public comments in relation to the importation of laminations, stacked cores and wound cores used for the production of transformers. As such, we have a history and vital interest in the North American transformer industry. Our position as an independent industry analyst provides us with data and unique perspectives which we are pleased to share with the Department of Energy (DOE) and colleagues in the industry.

For convenience, we use abbreviations in the text:

mt = metric tons (2,204 pounds)
K = '000 (example: 123K mt = 123,000 metric tons)
s. tons = short tons (US, 2000 pounds)

Wherever possible, a conversion of metric tons to US short tons is provided *in parens*

Example 123K mt (135,500 s. tons)

2.0 Executive Summary

- North America consumption of GOES in 2022 is estimated at 441K mt (486,000 s. tons) and 292K mt (322,000 s. tons) in the USA.
- Estimated consumption of GOES in 2022 for distribution transformers in the USA is at least 175K mt (193,000 s. tons), not including imported, finished transformers.
- Cliffs is not currently able to meet demand requirements for GOES in the USA. The transformer industry necessarily relies on imports of GOES into Canada and Mexico.
- Global capacity for production of GOES is estimated at 3.68 million mt (4.06 M s. tons).
- Global capacity for production of amorphous metal is estimated at 235K mt/yr..
- There is insufficient global production capacity of amorphous metal ribbon to support replacement of GOES in distribution transformers in the USA, even if production capacity were to be tripled in the USA over the next 3 to 5 years.
- Amorphous metal has approx. 35% core losses of GOES, which makes it ideal for low load factor applications where core losses dominate energy efficiency.
- A combination of lower stacking factor and lower magnetic induction for amorphous metal results in distribution transformers with 20-25% more weight than GOES core transformers for the same rating.
- GOES distribution transformers, of similar rating, but made to different efficiency standards, demonstrate different energy efficiencies up to 50% load factor but have similar performance at elevated load factors.
- Transformer energy efficiency measurements at 50% load only tell part of the story.
- Amorphous metal core distribution transformers are suitable and provide energy savings for low load factors ≤ 50% but have higher losses than GOES core distribution transformers at elevated load factors. Improvements are possible by adding mass.
- The combination of higher magnetic induction and saturation induction results in GOES transformer designs with higher efficiency than amorphous core designs, for the same rating, at elevated load factors, where I^2R losses dominate energy efficiency.
- In very simple terms, improvements in transformer efficiency are achieved through use of more raw materials. There are limitations to the availability of GOES and very great limitations to the availability of amorphous metal.
- Distribution transformer load factors will progressively increase as the network responds to rapidly increasing demand for EV charging, micro-grids and clean energy.

Recommendations and Comments

- The proposed new standards for improved transformer efficiency would have a huge, expensive impact on the USA transformer industry, which is currently unable to satisfy demand, and are not supported by raw material supplies, either currently or in the immediate future.
- It would seem prudent and recommended, if energy savings are to be achieved cost effectively, for the DOE to follow the lead of the European Union by introducing standards similar to ECO-2 for 3-phase transformers.
- It would seem prudent and recommended that introduction of new standards for improved transformer efficiencies for single phase transformers be delayed subject to evaluation of the effects and benefits of changes in standards for 3-phase transformers.
- The issue of domestic shortage of raw materials, especially specialty steel industry related, to support the Grid and distribution network, which is an issue of national security, should be referred by the DOE to the Department of Commerce for remedies.

3.0 GOES Consumption in North America

We use the definition of consumption as:

Consumption = Production plus imports minus exports

Apart from 2015 and prior, when Allegheny Ludlum was producing GOES, the only GOES production in North America comes from Cleveland-Cliffs (Cliffs), formerly AK Steel. Production data listed are estimates from MTC (**in metric tons**).

Import and export data for wide coil has been derived from ISSB, a highly respected source (with the possible exception of reporting of imports into Mexico, as explained, subsequently).

Data for imports and exports of laminations, stacked cores and wound cores for use in transformers is based on information provided by the Department of Commerce trade portal for harmonized tariff codes 8504.90.9634, 8504.90.9638, and 8504.909642. We have developed a proprietary method to convert the total $$ listed into tons of GOES, which are provided in the Consumption Table. Thus, the data, in tons, must be considered a very close estimate, but not absolute.

The Consumption Table (§ 3.4) does not capture tons of GOES imported into the USA in the form of finished transformers. This volume is captured as consumption in either Canada or Mexico.

3.1 Imports of GOES into the USA (metric tons)

2021	wide coil	slit coil	Total
JAPAN	72	22,949	23,021
SOUTH KOREA	16,939	1	16,940
RUSSIA	420	776	1,196
CHINA	37	302	339
BRAZIL		220	220
CANADA	9	171	180
MEXICO		38	38
AUSTRIA		34	34
SWEDEN		16	16
FRANCE		10	10
GERMANY		5	5
TOTAL	17,477	24,522	41,999

Source: ISSB, Metals Technology Consulting, Steel-Insights

2022 (12 Months)	wide coil	slit coil	Total
JAPAN		9,110	9,110
SOUTH KOREA	6,352		6,352
CANADA		2,100	2,100
MEXICO		859	859
POLAND		169	169
CHINA		148	148
RUSSIA		85	85
BRAZIL	49	5	54
ITALY	25		25
SWEDEN		18	18
SWITZERLAND		6	6
FRANCE		5	5
GERMANY		-	-
TOTAL	6,426	12,505	18,931

3.2 Imports of GOES into Canada (metric tons)

2021	wide coil	slit coil	Total
JAPAN	33,537	1,988	35,525
U S A	19,898	2,237	22,135
SOUTH KOREA	17,004	258	17,262
CHINA	12,744	414	13,158
RUSSIA	9,065	1,774	10,839
GERMANY	3,058	19	3,077
ITALY	22	837	859
INDIA	687	96	783
FRANCE	737	36	773
POLAND	260		260
SWITZERLAND	147		147
MEXICO	89	58	147
UAE		136	136
POLAND	-	101	101
TAIWAN	54		54
BRAZIL	21		21
UNITED KINGDO!	19		19
BELGIUM	9		9
TURKEY	1		1
TOTAL	97,352	7,954	105,306

Source: ISSB, Metals Technology Consulting, Steel-Insights

2022 (12 Months)	wide coil	slit coil	Total
U S A	37,226	1,679	38,905
JAPAN	22,365	1,498	23,863
SOUTH KOREA	12,790	99	12,889
CHINA	7,953	365	8,318
SLOVENIA		6,683	6,683
RUSSIA	5,419		5,419
POLAND	2,138	296	2,434
ITALY	2	1,774	1,776
GERMANY	1,614	32	1,646
INDIA	200		200
FRANCE	199		199
MEXICO	28	168	196
SWEDEN	107		107
UNITED KINGDO!	24		24
TOTAL	90,065	12,594	102,659

Source: ISSB, Metals Technology Consulting, Steel-Insights

3.3 Imports of GOES into Mexico (metric tons)

2021	wide coil	slit coil	Total
JAPAN	63,236	645	63,881
CHINA	55,569	119	55,688
RUSSIA	9,751	4,845	14,596
U S A	3,326	1,100	4,426
POLAND	3,017	494	3,511
SOUTH KOREA	3,036	299	3,335
GERMANY	1,623	106	1,729
CZECH REPUBLIC	1,362		1,362
TAIWAN		137	137
BRAZIL	113		113
ITALY	103		103
FRANCE	20	13	33
CANADA		7	7
SPAIN		5	5
UKRAINE		3	3
TOTAL	141,156	7,773	148,929

Source: ISSB, Metals Technology Consulting, Steel-Insights

2022 (12 Months)	wide coil	slit coil	Total
JAPAN	64,769		64,769
CHINA	52,830	233	53,063
RUSSIA	22,725		22,725
U S A	6,013	4,133	10,146
POLAND	6,599		6,599
SOUTH KOREA	1,490	8	1,498
GERMANY		218	218
TOTAL	154,426	4,592	159,018

Source: ISSB, Metals Technology Consulting, Steel-Insights

Data for wide coil imports into Mexico are derived from exports from the declared country of origin (not declared imports into Mexico, due to IMMEX withholding of data for 100% export).

3.4 Consumption of GOES in North America, ('000 metric tons)

USA

	2015	2016	2017	2018	2019	2020	2021	2022f
Production of GOES, AK + ATI (2015)	265	219	198	213	193	153	206	220
Imports - Wide Coil	28	36	68	59	28	25	42	19
Imports - Laminations for transformers	5	8	6	5	12	12	12	13
Imports - Stacked cores for transformers	1	3	5	5	7	6	6	8
Imports - Wound cores for transformers	7	23	27	31	80	102	83	98
Total Imports	41	70	106	100	127	145	143	138
Exports, wide coil	100	62	47	48	46	31	48	66
Consumption	206	227	257	265	274	267	301	292

Canada

	2015	2016	2017	2018	2019	2020	2021	2022f
Production	0	0	0	0	0	0	0	0
Imports, wide coil	69	58	88	90	70	94	105	103
Exports, wide coil	1	1	1	1	0	2	2	3
Exports, Laminations for transformers	3	4	3	4	8	7	6	6
Exports, Stacked cores for transformers	1	1	3	3	4	3	3	5
Exports, Wound cores for transformers	3	12	14	16	31	41	38	46
Total exports	8	18	21	24	43	53	49	60
Consumption	61	41	68	66	27	41	56	43

Mexico

	2015	2016	2017	2018	2019	2020	2021	2022f
Production	0	0	0	0	0	0	0	0
Imports, wide coil	100	102	84	111	135	145	149	159
Exports, wide coil	6	5	13	9	7	6	5	2
Exports, Laminations for transformers	3	4	3	4	4	4	6	7
Exports, Stacked cores for transformers	1	1	3	3	3	3	2	3
Exports, Wound cores for transformers	3	12	14	16	26	39	23	24
Total Exports	9	17	27	25	33	45	28	26
Consumption	91	85	57	86	102	100	121	133

North America

	2015	2016	2017	2018	2019	2020	2021	2022f
Production	265	219	198	213	193	153	206	220
Imports, wide coil	197	196	240	260	233	264	296	281
Imports, cores, stacks, lams (not Can, Mex)	0	1	1	2	2	2	3	6
Exports, wide coil	100	62	47	48	46	31	48	66
Consumption	362	355	393	428	382	389	457	441

Source: ISSB, Metals Technology Consulting & Steel-Insights estimates

Despite limitations in the data identified in § 3.0 previously, there are several very clear conclusions from the data on consumption of GOES in North America:

- Imports of wound cores into the USA has increased dramatically from both Canada and Mexico since 2017, primarily driven by (1) the price difference for GOES between Cliffs

USA prices and international GOES prices, and, to a lesser extent (2) the difference in labor costs.

- Data for imports of stacked cores into the USA appear to be lower than would be expected from our industry experience.
- Canada (2 major suppliers) has exceeded Mexico and become the leader in export of wound cores into the USA.
- Imports of laminations, stacks and cores for transformers are significant, being approximately 38% of GOES consumption in the USA.
- Based on the estimated production and consumption data, Cliffs is not currently able to meet demand requirements for GOES in the USA. The transformer industry necessarily relies on imports of GOES into Canada and Mexico to supplement Cliff's production in the USA.
- If conventional wisdom is used wherein the use of GOES is split 60/40 between distribution and power transformers, then the approximate consumption of GOES for distribution transformers in the USA is (at least) 175K mt (193,000 s. tons). This does not include GOES imported as assembled transformers, as noted previously in § 3.3.

4.0 Supply of Core Materials to Support Distribution Transformer Manufacture in the USA

4.1 Global Supply of GOES

Total capacity for production of GOES is estimated at 3.68 million metric tons (4.06 million s. tons), produced by 11 integrated suppliers and 5 re-rollers (4 in China), with approximately 32% produced as regular grain oriented (RGO) and 68% produced as high permeability grades (HiB).

Barriers for entry into production of GOES are high, including:

- Very high capital costs for few tons
- Sophistication of equipment, especially limited productivity precision cold rolling mills
- Technology and patent restrictions

4.2 Global and US supply of Amorphous Metal Ribbon

Total capacity for production of amorphous metal ribbon is estimated at:

Hitachi Metglas, Conway NC		40,000 mt/yr.
Hitachi Metglas, Japan		60,000 mt/yr.
China (4 suppliers)		135,000 mt/yr.
	TOTAL	235,000 mt (259,000 s. tons)

There have been intense patent disputes between Hitachi and the Chinese with the result that Hitachi has consolidated production in Japan.

The practical consequence is that there are essentially only 2 global suppliers of amorphous metal; Hitachi and the Chinese.

4.3 Production Volumes to Support Distribution Transformer Core Manufacture

§ 3.4 shows that the current USA distribution transformer industry consumed at least 175K mt of GOES in 2022.

Total global production capacity for amorphous metal is 235K mt (259,000 s. tons), which is mostly consumed in China.

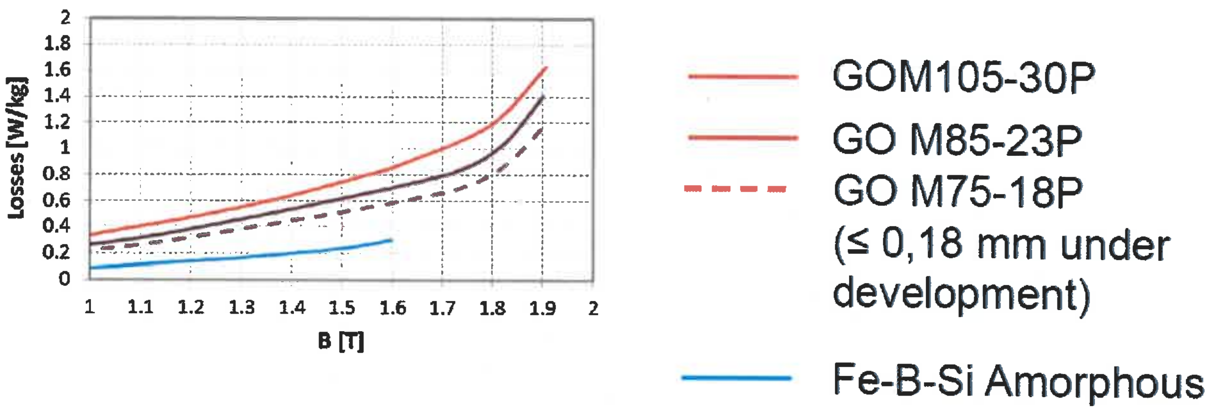
Clearly, there is insufficient global production capacity of amorphous metal ribbon to support replacement of GOES in distribution transformers in the USA, even if production capacity were to be tripled in the USA over the next 3 to 5 years.

5.0 Comparison of Material Properties and Effects on Transformer Design and Performance

5.1 Core Loss, Thickness, and Resistivity

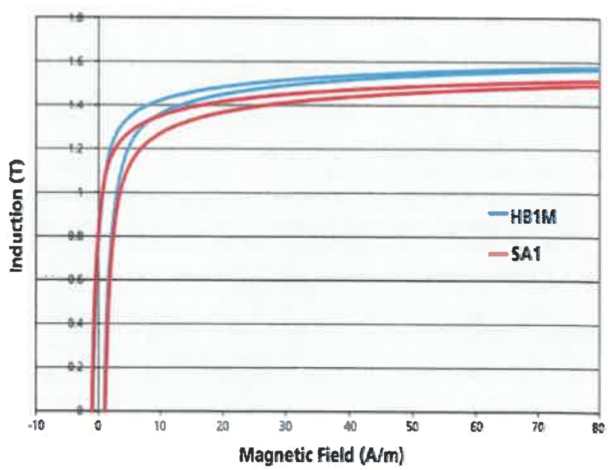
Core loss is the heat generated in a magnetic material, described by the simplified Steinmetz equation as being proportional to the square of both thickness and magnetic induction, and inversely proportional to resistivity. Amorphous metal has a significant advantage over GOES for both thickness and resistivity:

	Thickness	Resistivity, Ω .m (x10^{-8})
Amorphous metal	0.025 mm	120
GOES, HiB	0.23 mm	51



5.2 Magnetic Induction (B, Tesla) and Saturation Magnetic Induction

Magnetic Induction, B, is a measure, in Tesla, of the magnetic field induced in a magnetic material (or core) by an external applied field H (the windings), measured in Amps/meter



Material	Magnetic Induction B8, Tesla, @ 800 A/m	Saturation Magnetic Induction Bs, Tesla
Regular grain oriented, 0.23 mm	1.84	2.02
HiB grain oriented, 0.23 mm	1.92	2.02
Amorphous metal, HB1M	1.52	1.63

The consequence of a lower Magnetic Induction for amorphous metal is that a **higher current is required, or a higher number of turns, or both (ampere-turns) compared to GOES, to produce the same induced field in the core.**

5.3 Stacking (or Lamination) Factor

Stacking factor is a measure of the amount of iron or magnetic material in an assembly compared to a solid core of the same dimensions, without surfaces or coatings.

Material	Stacking Factor %
Regular grain oriented, 0.23 mm	96
HiB grain oriented, 0.23 mm	96
Amorphous metal, HB1M	88

5.4 Effect of Material Properties on Transformer Design

Transformer design is a compromise between material properties and total costs of materials, to achieve specified minimum transformer efficiencies. As such, designs will differ according to whether minimum efficiency is specified under conditions of No Load Losses (NLL), 50% Load Losses, or total cost of ownership. (TCO or TOC).

As a guide, some of the differences between transformer designs based on either GOES cores or amorphous metal cores are:

- Average transformer design operating induction levels
  GOES induction levels tend to be 1.45 to 1.50 Tesla (below the "knee" of the core loss vs. magnetic induction curve)
  Amorphous metal induction levels tend to be 1.37 to 1.42 Tesla (to take maximum advantage of the low core loss and provide a safety factor below saturation)

  As implied by the core loss vs. induction curve, it is possible to reduce losses, thereby improving efficiency, by adding mass to the core. The compromise then comes from the balance between the additional costs of materials (both core and winding) vs. the improvements in efficiency.

- Core mass.
  Compared to a GOES core for an average transformer, an amorphous core must
  1. Increase mass by 12% to account for the stacking factor
  2. Increase mass by 18-22% to account for lower magnetic induction and a safety factor for high loads

Total mass increase 30-35%

- Copper or aluminum windings
  (aluminum is sometimes eliminated as a choice for high efficiency windings)
  Compared to a GOES core for an average transformer, an amorphous core design
  1. Winding mass /length increases by 15%to account for stacking factor.
  2. Winding cross section may or may not increase by 5% (to account for higher current to achieve magnetic core induction) depending on the specified test conditions.
     Total mass increase 15-20%

- Transformer mass
  Based on the above, overall transformer mass increases by 20-25% including insulation, oil, steel shell and radiators. Transformer oil weight typically increases for amorphous core designs due to the larger core and winding assembly.

In very simple terms, improvements in transformer efficiency are achieved through use of more raw materials. There are limitations to the availability of GOES and very great limitations to the availability of amorphous metal, as shown in §§ 3.4, 4.1 and 4.2.

6.0 Effect of Transformer Load Factor on Transformer Efficiency

It is well understood that no-load loss (NLL) tests are not necessarily representative of transformer efficiency or losses in operation since NLL tests provide only a measure of core losses and I^2R losses from the primary. A more indicative measure of transformer efficiency comes from losses at 50% load, which is the standard used by DOE to rate transformer performance.

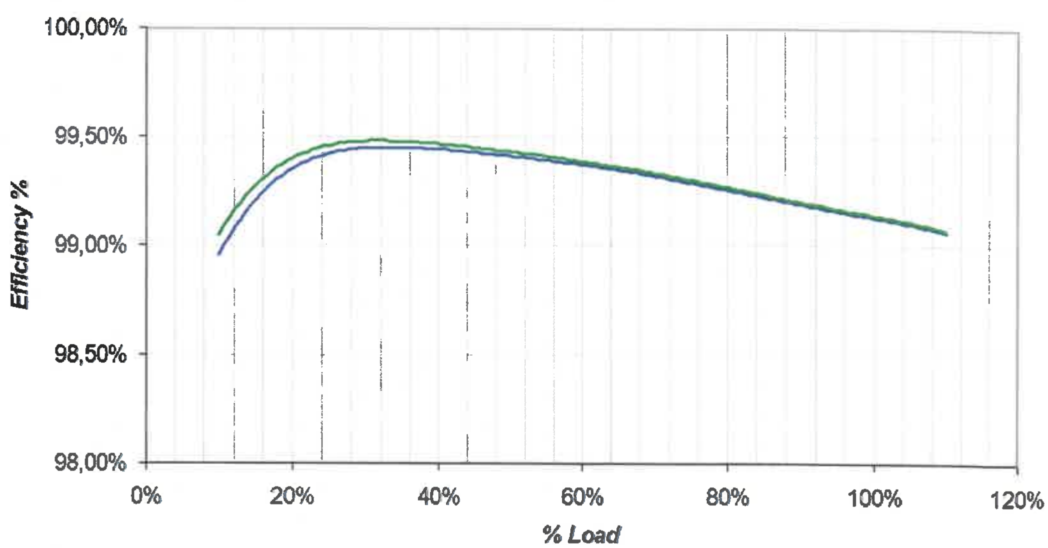
But this does not tell the whole story.

An example of the relationship between transformer efficiency and load factor, for GOES cores, is shown as follows:

Comparison of Transformer Efficiency vs. Load Factor for EU Standard ECO-1 and ECO-2 designs for 3-phase oil filled 500kVA Distribution Transformer

				Load %	Efficiency % ECO-1	Efficiency % ECO-2
				10%	98.96%	99.05%
Rated Power	500	kVA	ECO-1	20%	99.36%	99.41%
No Load Losses	489	W		30%	99.44%	99.48%
On Load Losses	3900	W		40%	99.45%	99.47%
cos φ	1			50%	99.42%	99.44%
				60%	99.37%	99.39%
Rated Power	500	kVA	ECO-2	70%	99.32%	99.33%
No Load Losses	440	W		80%	99.26%	99.27%
On Load Losses	3900	W		90%	99.20%	99.21%
cos φ	1			100%	99.13%	99.14%
				110%	99.06%	99.07%
	Peak Efficiency ECO-1			35.41%	99.45%	99.48%
	Peak Efficiency ECO-2			33.59%		

Source: Dr Franco Marini, SIM, Italy



Source: Dr. Franco Marini, SIM, Italy

The observations are, for GOES cores:

1. There is a measurable improvement in transformer efficiency, comparing ECO-1 and ECO-2 designs at low load factors, but this difference rapidly disappears above 50% load factor, such that efficiencies become similar.
2. Transformer efficiency measurement at 50% load factor provides a valid indication of efficiency, and hence, potential energy savings, BUT only for load factors ≤ 50%.

The relationship between transformer efficiency and load factor is different for transformers using amorphous metal cores, which demonstrate higher efficiencies, compared to GOES cores, at load factors ≤ 50%.

Above 50% load factors, distribution transformer efficiency drops off more rapidly for amorphous cores, compared to efficiency for GOES cores due to the effects of higher I^2R losses from:

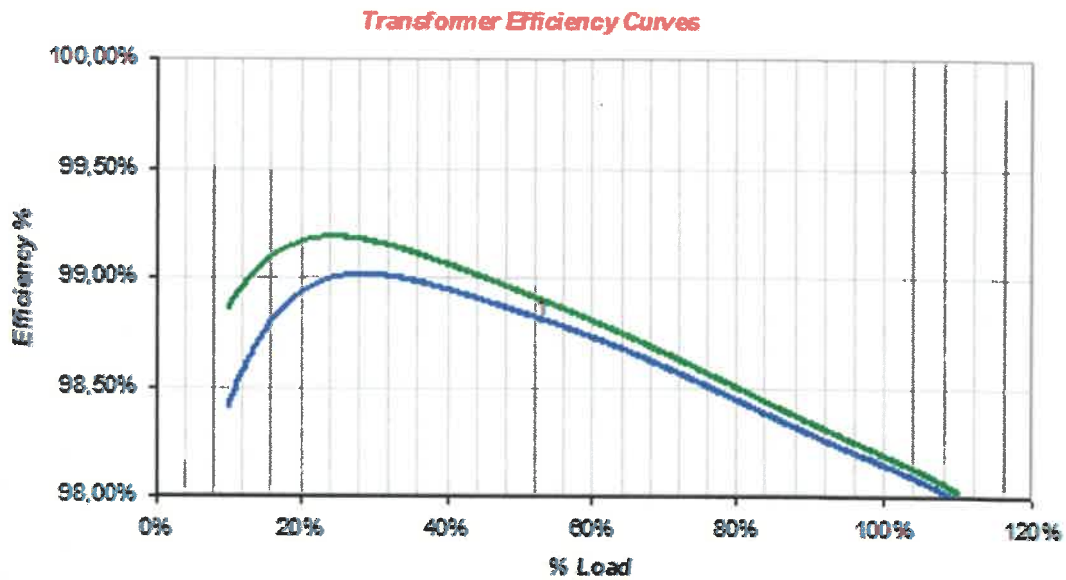
1. Higher ampere-turn requirement for amorphous metal from the lower Magnetic Induction, and
2. Saturation effects from the lower Saturation Magnetic Induction, B_S

An example of the relationship between transformer efficiency and load factor, for an ECO-1 design with a GOES core, and an ECO-2 design with an amorphous core is shown as follows:

Comparison of Transformer Efficiency vs. Load Factor for EU Standard ECO-1, GOES core, and ECO-2, amorphous core, designs for 3-phase oil filled 100kVA Distribution Transformer

				Load %	Efficiency % ECO-1 GOES	Efficiency % ECO-2 Amorphous
				10%	98.40%	98.86%
Rated Power	100	kVA	ECO-1 GOES Core	20%	98.94%	99.17%
No Load Losses	145	W		30%	99.00%	99.16%
On Load Losses	1750	W		40%	98.95%	99.06%
cos φ	1			50%	98.85%	98.94%
				60%	98.72%	98.80%
Rated Power	100	kVA	ECO-2 Amorphous core	70%	98.59%	98.65%
No Load Losses	99	W		80%	98.44%	98.50%
On Load Losses	1750	W		90%	98.29%	98.34%
cos φ	1			100%	98.14%	98.19%
				110%	97.98%	98.04%
Peak Efficiency ECO-1, GOES core				28.79%	99.00%	99.16%
Peak Efficiency ECO-2, Amorphous core				23.66%		

Source: Dr Franco Marini, SIM, Italy



At load factors ≤ 50%, transformer efficiency is better for the amorphous core, as would be expected from the ECO-2 design, compared to the ECO-1 design. The more important observation is that transformer efficiencies converge at load factors ≥ 50%, as shown previously for the 500kVA transformer example.

The conclusion is that it is possible to achieve significant energy savings using ECO-2 designs, utilizing improved grade GOES, without major disruptions to materials or the transformer manufacturing process.

It is possible to get amorphous-core transformer designs that have lower total losses than GOES designs over the entire loading range 0-100% (and beyond) by adding mass to the core. Higher loss >50% load is not ubiquitous for amorphous core transformers but is driven by the DOE's 50% minimum efficiency testing requirement. When customers specify and buy using either a total owning cost formula or a maximum total loss requirement, the designs that are built are substantially better than base DOE designs.

Distribution transformer load factors will progressively increase as the network responds to rapidly increasing demand for EV charging, introduction of micro-grids, and expansion of clean energy projects. Thus, careful consideration needs to be given to specifications for testing of transformers compared to real life conditions which will frequently exceed 50% average load factors.

7.0 Comparison of EU ECO-2 and DOE Distribution Transformer Energy Efficiency Standards

The European Union announced the introduction of Phase 2 energy efficiency standards for Distribution Transformers, ECO-2, in 2016 following successful implementation of Phase 1, or ECO-1, in July 2015. The ECO-2 regulations started in January 2021 and were fully implemented in January 2022.

The effect of the regulations involved converting the cores of 3-phase distribution transformers from GOES with core loss levels 105/120 (achieved using regular grain oriented, 0.23 mm and 0.27 mm) to GOES with core loss levels 080/085 (achieved using HiB grain oriented, 0.23 mm).

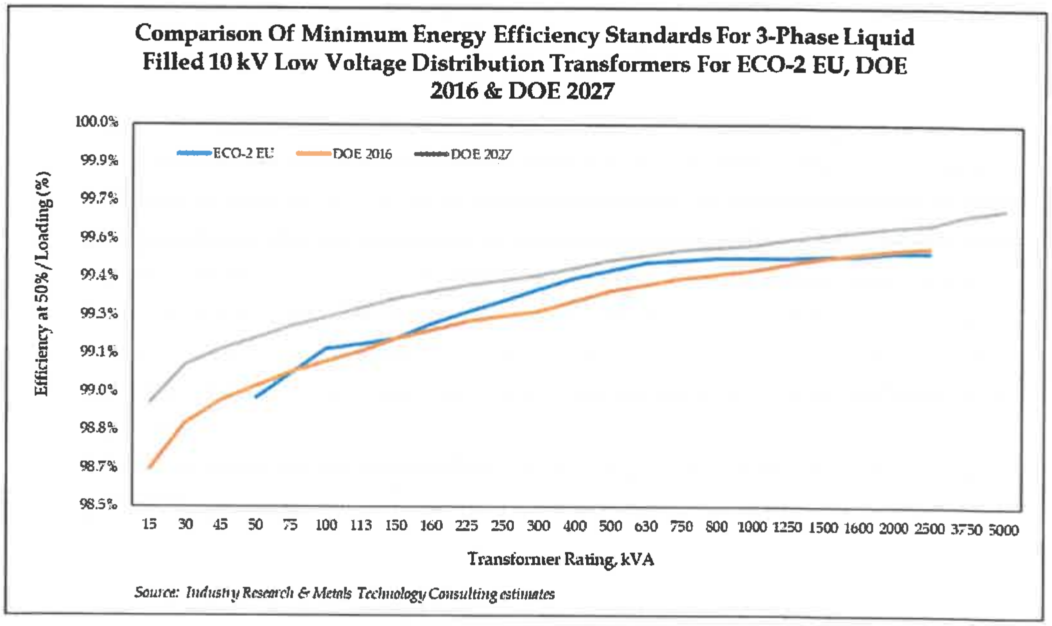
A comparison of actual energy efficiency limits, for specific kVA ratings, between ECO-2 and DOE current standards (2016) and proposed DOE standards (2027), is shown in the Figures below. In general, ECO-2 standards are an improvement on DOE 2016 standards but do not achieve DOE 2027 levels. We note that the extended time period for notification of change, together with the actual revised levels for energy efficiency standards, allowed the EU regulations to be implemented with only minor disruptions to the European transformer industry and GOES supply chain.

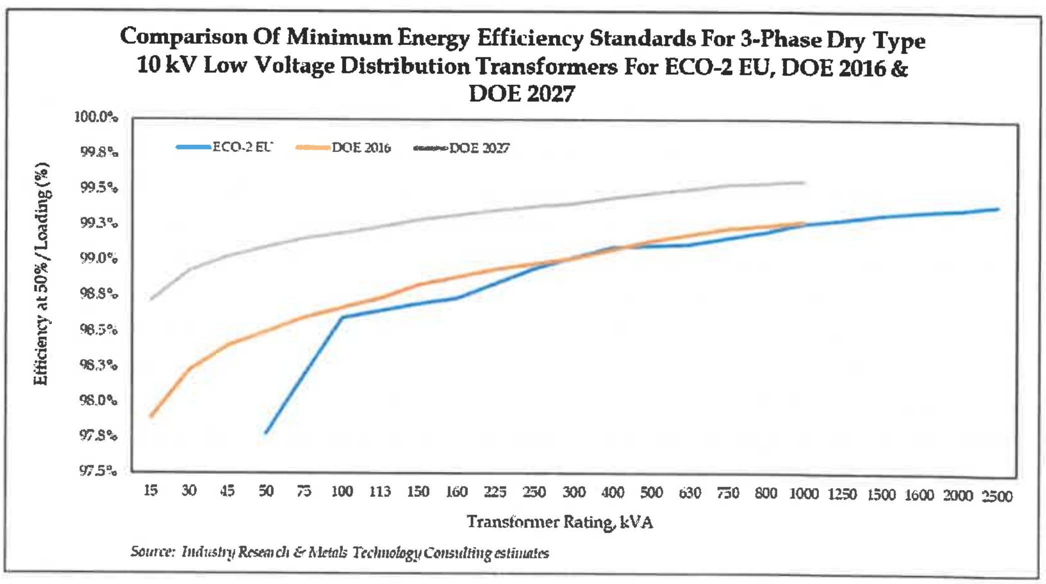
Min. Energy Efficiency Standards, Distribution Transformers 10 kV low voltage, 3-phase, liquid filled

kVA	kVA	ECO-2 EU	DOE 2016	DOE 2027
	15		98.65	98.91
30	30		98.83	99.06
	45		98.92	99.12
50		98.93		
	75		99.03	99.21
100		99.12		
	112.5		99.11	99.28
	150		99.16	99.32
160		99.22		
	225		99.23	99.37
250		99.31		
	300		99.27	99.41
400		99.40		
500	500	99.43	99.35	99.47
630		99.46		
	750		99.40	99.51
800		99.48		
1000	1000	99.48	99.43	99.53
1250		99.48		
	1500		99.48	99.57
1600		99.49		
2000	2000	99.50	99.51	99.60
2500		99.5	99.52	99.61
	3750			99.65
	5000			99.67

Min. Energy Efficiency Standards, Distribution Transformers 10 kV low voltage, 3-phase, dry type

kVA	kVA	ECO-2 EU	DOE 2016	DOE 2027
	15		97.89	98.72
30	30		98.23	98.93
	45		98.40	99.03
50		97.78		
	75		98.60	99.16
100		98.60		
	112.5		98.74	99.24
	150		98.83	99.29
160		98.74		
	225		98.94	99.36
250		98.95		
	300		99.02	99.41
400		99.10		
500	500		99.14	99.48
630		99.12		
	750		99.23	99.54
800		99.21		
1000	1000	99.27	99.28	99.57
1250				
	1500			
1600		99.35		
2000	2000	99.37		
2500		99.40		





The Figures above, which apply to 3-phase distribution transformers, show that ECO-2 standards generally provide energy efficiency benefits compared to existing DOE 2016 transformer efficiency standards, but not at the levels proposed by DOE 2027. Experience has shown that ECO-2 standards can be met with transformers using HiB GOES cores, which operate effectively at a full range of load factors, including a tolerance for overload conditions.

It would seem prudent, if energy savings are to be cost effective, for the DOE to follow the lead of ECO-2 standards. Elevated standards for distribution transformers, such as DOE 2027, which require the use of amorphous metal, could be considered at a later time following experience with the change in design requirements and improvements in raw material supply chains.

Similar to ECO-2, it would seem prudent to delay introduction of new energy efficiency standards to single phase transformers, and subsequent changes in core design, until experience has been developed with new core designs in 3-phase transformers. It is likely (in our opinion) that the use of HiB GOES might be a better raw material for cores, based on both total transformer cost plus energy savings, for domestic household situations with a combination of variable load factors and the requirement to service EV charging (at higher load factors). Delay of introduction of new efficiency standards to single phase transformers would also provide time for a re-adjustment of the raw material supply chain.

8.0 Unintended Consequences (Collateral Damage)

If, through happenstance, the proposed DOE energy efficiency standards are implemented without reduction or modification in scope or timing, forcing the substitution of amorphous metal ribbon cores in place of GOES, then:

1. The costs for domestic production of GOES will increase substantially, since costs of steel production are related to volume, and the large volume of GOES supplied for distribution transformers will be drastically reduced. This will jeopardize refurbishment, resilience, and upgrade of the Grid, which the Department of Commerce has designated as an issue of national security.
2. The supply chain for amorphous metal cores will be directed to a single Japanese company, irrespective of domestic licensing, accompanied by supply from China. This scarcely qualifies as "Building US Better".
3. Manufacture of amorphous metal cores is difficult and highly labor intensive. Core manufacture will be further driven out of the USA and possibly even out of North America, especially to China.
4. Use of amorphous metal cores requires different mandrels, winding, assembly processes, and equipment, including specialty annealing equipment. The costs and time required for implementation are significant and would be a major cost burden on transformer manufacturers.
5. A 20-25% increase in mass for pole-mount distribution transformers may necessitate a revision to standards and practices for poles used in conjunction with distribution of electricity. Thus, amorphous core and GOES core distribution transformers of the same rating, may not necessarily be interchangeable at a site installation level.

9.0 Comments About the GOES Steel Industry

GOES is the most difficult technology of all flat rolled steel products. As noted, the barriers to entry are huge, including technology, high capital investment, and lack of fungibility of equipment. Cliffs (formerly AK Steel), being the only producer of GOES in North America, should be congratulated for staying in the business in good times and bad. Cliffs has been criticized for high costs/prices, the legacy of equipment dating back to the 60's and 70's, with minor upgrades and refurbishment. But the problem does not necessarily lie with Cliffs. There are no significant incentives, such as investment tax credits, applied R&D grants and other credits, etc., for US specialty steel companies to invest in new equipment. It is no surprise that US specialty steel prices (electrical, stainless, high alloy, etc.) are out of step with the rest of the world.

The facts, relating to the GOES industry, are:

- Total global capacity for GOES production is 3.84 million mt/yr.(4.23 million s. tons) , compared to 2.5 billion mt/yr. (2.76 billion s. tons) for all global steel capacity
- China controls an estimated 41% of global capacity for GOES production.
- All Chinese equipment for GOES was installed after 2010, mostly with central and/or provincial government subsidies and/or low cost loans.
- The Department of Commerce has recognized the grid, and by inference, the distribution network, as an issue of national security.

While beyond the immediate scope of the DOE proposals to improve energy efficiency, we have documented in this report that there is a major shortfall in domestic and global supply of raw materials, which will prevent or severely limit immediate implementation of the highest energy efficiency standards for transformers. We note:

- Cliffs has an estimated GOES capacity of 220K mt/yr. (242,000 s. tons) compared with a North American consumption of 450K mt/yr. (496,000 s. tons).
- Hitachi USA has current production capacity of 40K mt/yr. (44,100 s. tons) which, even if doubled and supplemented by 60K mt/yr. (66,100 s. tons) from Japan, compares with a USA distribution transformer consumption of 175K mt/yr. (193,000 s. tons)
- The US and North American distribution transformer industry is operating at maximum capacity, unable to satisfy demand, something that is expected to continue for several years.

Indeed, this is an issue of national security and importance which should be referred to the Department of Commerce for remedies.

10.0 Recommendations and Comments

10.1 The proposed new standards for improved transformer efficiency will have a huge, expensive impact on the USA transformer industry, which is currently unable to satisfy demand, and are not supported by raw material supplies, either currently or in the immediate future.

10.2 It would seem prudent and recommended, if energy savings are to be achieved cost effectively, for the DOE to follow the lead of the European Union by introducing standards similar to ECO-2 for 3-phase transformers.

10.3 It would seem prudent and recommended that introduction of new standards for improved transformer efficiencies for single phase transformers be delayed subject to evaluation of the effects and benefits of changes in standards for 3-phase transformers. This would also provide time for adaptation by the raw materials supply chain.

10.4 The issue of domestic shortage of raw materials, especially specialty steel industry related, to support the Grid and distribution network, which is an issue of national security, should be referred by the DOE to the Department of Commerce for remedies.

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