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Subject: NOPR EERE-2019-BT-STD-0018

HVOLT Inc., Philip J. Hopkinson P.E. President and CEO, is a Power and Distribution Transformer Registered Professional Engineering Consulting Company, located in Charlotte, NC. As founder, I have been involved with Distribution Transformer Energy Efficiency activities since 1991, when I first met with a Congressional Taskforce that was investigating Distribution Transformer energy efficiency. Shortly thereafter, I worked closely as a member of NEMA to assess what might be done to reduce core losses and winding losses in distribution transformers. In 1996, I led a NEMA Taskforce to issue NEMA TP-1 It was based on several important concepts:

1. Doable with known technology
2. Economical in that it pays for itself with a 3–5-year payback.
3. Results in real energy savings.

After some analysis of the various power ratings and applications, we concluded that Low Voltage Dry transformers would be evaluated at 35% of Nameplate load, while all medium voltage transformers would be evaluated at 50% of Nameplate load.

Each of the concepts that were imbedded in the principles of NEMA TP-1 made sense then and does today, particularly doable with known technology and not needing an invention. We applied that to materials as well. Materials that were readily available were considered good prospects, and materials that were not readily available would not be considered.

The DOE initially adopted NEMA TP-1 for rules. In later rulemakings, they became more actively involved, using Oakridge National Laboratory and Lawrence Berkeley National Laboratory, as well as Optimized Program Services Software (OPS), to analyze design impacts. NEMA TP-1 was discontinued, and DOE-mandated efficiencies evolved, the most recent being the rules of 2016. Those rules have worked out quite well for the industry and serve as a minimum required efficiency. There are a few cases of Total Owning Cost minimization to justify greater efficiencies, but most of the industry is satisfied with the 2016 rules.

The new 2022 NOPR for 2027 implementation has resulted in loss reductions per the following table:

Table IV.8 Efficiency Levels as Percentage Reduction of Baseline Losses

Equipment Type	EL				
	1	2	3	4	5 (Max-tech)
Liquid-immersed					
≤ 2500 kVA	2.5	5	10	20	40
> 2500 kVA	40*	5**	10**	20**	40**
Low-voltage Dry-type					
1ϕ	10	20	30	40	50
3ϕ	5	10	20	30	40
Medium-voltage Dry-type					
< 46 kV BIL	5	10	20	30	40
≥ 46 and < 96 kV BIL, and ≤ 2500 kVA	5	10	20	30	40
≥ 46 and < 96 kV BIL, and > 2500 kVA	43*	10**	20**	30**	40**
≥ 96 kV BIL and ≤ 2500 kVA	5	10	20	30	35
≥ 96 kV BIL and > 2500 kVA	34*	10**	20**	30**	35**

*Equipment currently not subject to standards. Therefore, reduction in losses relative to least efficient product on market.

**Reduction in losses relative to EL1

Figure 1 shows the % total loss reductions that the DOE is trying to implement at the measured efficiency points of 35% load for Low Voltage, and 50% load for medium voltage transformers.

It is not clear why the DOE has chosen to selectively implement stricter standards on some of the products. From careful analysis, several of these proposed efficiencies have clearly hit the proverbial brick wall, after which large amounts of material thrown at the designs result in very little improved efficiency.

Today, through HVOLT Inc., I work closely with NEMA, as well as non-NEMA transformer manufacturers, core steel maker Cleveland Cliffs, the Copper Alliance Association, and other materials suppliers. In addition, I am a life Fellow in IEEE, specializing in the Transformers Committee (attending my first meeting in 1972), the Technical Adviser to the US National Committee for IEC TC 14 since 1996. I have worked with members of Edison Electric Institute, and with members of the American Public Power Association and the National Rural Electric Association. In the IEEE transformers committee, I hold regular meetings as task force leader of activities associated with DOE Energy Efficiencies issues for Distribution Transformers. Most recently, my Task Force membership is approximately 150 members, all with deep interest as stakeholders, manufacturers, users, government representatives and standards associations from all countries. They look to my task force to keep them informed and to help represent their interests.

I am submitting comments for your consideration after careful analysis of the NOPR and discussions with the various groups mentioned above:

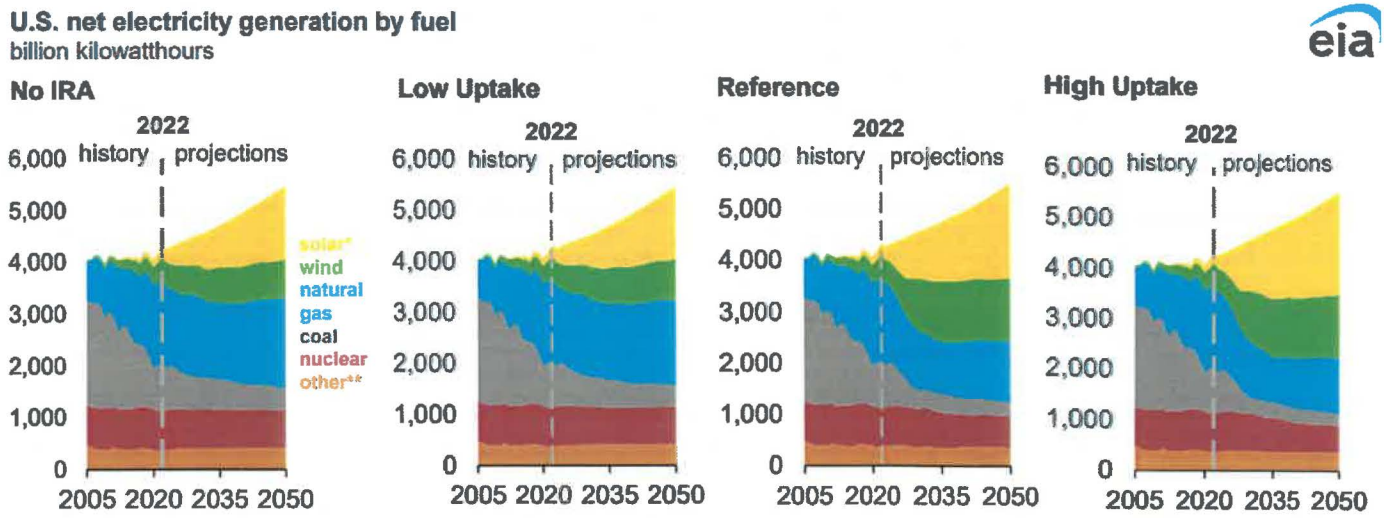
A. **Loading:** A very important national and international consideration that the DOE has not addressed is Loading increases, associated with Electric Vehicles (EV's) and conversions from Natural Gas heating to Electric Heat pumps. The DOE uses a 30-year horizon for its intended rules. The Edison Electric Institute (EEI) has estimated that electric use in the country could rise by up to 50% over the next 5-10 years from such loads. This certainly will impact Distribution transformer RMS-equivalent loads and make load loss reductions considerably more important than Core Loss reductions. Steve Rosenstock of EEI supplied a set of comparisons from EIA (Energy Information Administration) data for 2021 and 2022 that shows year to year total US electrical energy generation from all sources **increased by 3.3%.** It is our belief that this trend will continue and increase.

Fuel	Facility Type	December 2022 YTD	December 2021 YTD
Net Generation (Thousand Megawatthours)			
Coal	Utility Scale Facilities	828,993	897,885
Petroleum Liquids	Utility Scale Facilities	16,274	11,665
Petroleum Coke	Utility Scale Facilities	7,109	7,511
Natural Gas	Utility Scale Facilities	1,689,465	1,579,361
Other Gas	Utility Scale Facilities	11,884	11,397
Nuclear	Utility Scale Facilities	771,537	778,188
Hydroelectric Conventional	Utility Scale Facilities	261,999	251,585
Renewable Sources Excluding Hydroelectric	Utility Scale Facilities	650,870	563,682
... Wind	Utility Scale Facilities	434,812	378,197
... Solar Thermal and Photovoltaic	Utility Scale Facilities	145,598	115,258
... Wood and Wood-Derived Fuels	Utility Scale Facilities	36,569	36,463
... Other Biomass	Utility Scale Facilities	16,889	17,790
... Geothermal	Utility Scale Facilities	17,002	15,975
Hydroelectric Pumped Storage	Utility Scale Facilities	-6,034	-5,112
Other Energy Sources	Utility Scale Facilities	11,038	12,140
All Energy Sources	**Utility Scale Facilities**	**4,243,136**	**4,108,303**
		+3.3%	

Figure 2 shows the actual load growth from 2021-2022 by category.

The EIA's 2023 forecast, just published this month, is always very conservative but has now upped the growth of electrical energy to 0.9%/yr. from <0.5%/yr., or about twice as much as the 2022 forecast. This now amounts to a 35% increase from 2022 through 2050. Recognizing the actual 3.3% growth from 2021-2022, it is likely that the future growth will be much more rapid and quickly drives home the importance of low transformer load loss over core loss reductions. Chart 14 from the DOE's EIA 2023 forecast shows their new projections graphically. This new report, with twice as much growth over the year earlier report, is a significant factor that should cause the DOE to reassess its report.

Solar and wind generate a majority of U.S. electricity by 2050 in the Reference and High Uptake cases



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: IRA=Inflation Reduction Act
*Includes utility-scale and end-use photovoltaic generation and excludes off-grid photovoltaics.
**Includes petroleum, conventional hydroelectric power, geothermal, wood and other biomass, pumped storage, non-biogenic municipal waste in the electric power sector, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Figure 3 shows chart 14 from the 2023 EIA recently released forecast

B. **Concentration on Amorphous Core products with the exclusion of GOES.**

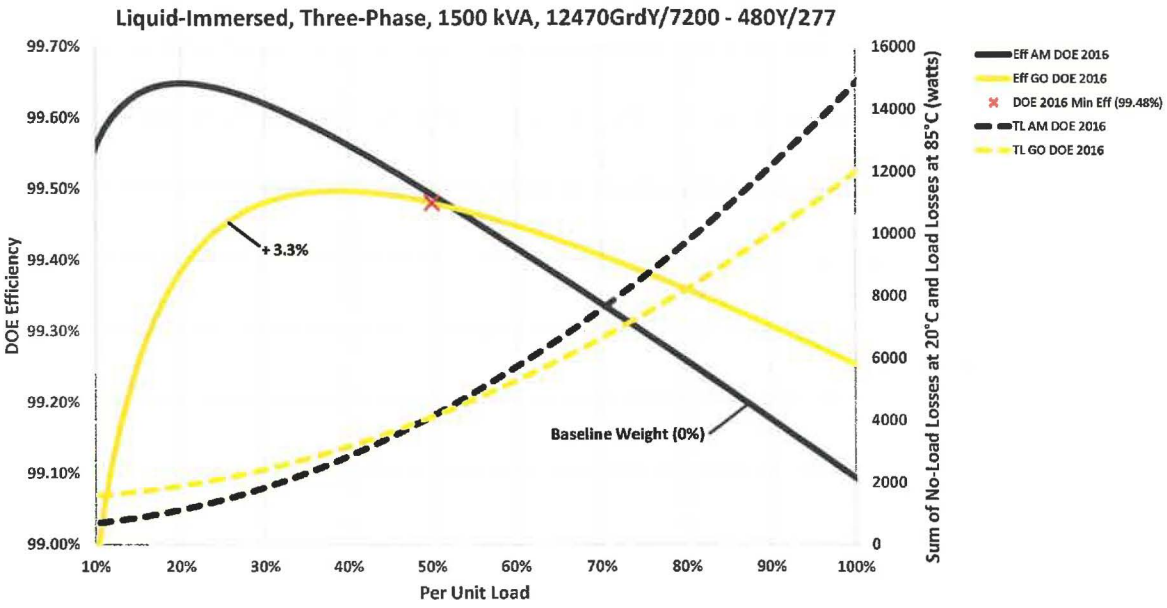


Figure 4 shows a 1500 kVA design comparison between GOES in yellow and Amorphous in black that meet the DOE 2016 efficiencies.

1. With large increases in load growth over the forecast, it does not seem to be appropriate or wise to concentrate on Amorphous Cores, which claim to have peak efficiency at 20% load. If we look at only the 2016 plots above of % efficiency versus % load, it is clear that amorphous cores indeed hit peak efficiency at 20% load. Interestingly, transformers with amorphous cores are not as efficient at greater than 50% load as GOES transformers. In fact at 100% load, amorphous core transformers have 50% higher total loss than GOES. With loading increasing so fast, I recommend that the DOE reconsider the amorphous direction, and not implement any standards that exclude GOES.

2. A second issue is audible noise. It is always louder with Amorphous than with GOES. A large manufacturer of 3-phase padmounted transformers reported **an average of 14+ % louder for amorphous**, which is quite objectionable in many locations. Every power rating is affected, because amorphous is always operated close to the saturation region to minimize cost, and the peaks of every cycle of 60 Hz current tip into saturation. Contrast that to GOES material which operates at extremely low flux densities to meet efficiency rules, and is never close to saturation.

3. A third major issue is capacity. The present Distribution transformer market consumes more than 200,000 metric tons of GOES material annually. Amorphous consumption is reported to be about 3% of the market. The proposed NOPR is intended for 2027 implementation. If that were to take place and 85% of the Distribution Transformer production were to convert to Amorphous (leaving only the largest transformers on GOES), then Metglas owner Bain, by way of Proterial (current owner of Metglas) would need to add close to 200,000 metric tons of capacity. Metglas has said that they believed that they could probably add up to 70,000 tons. If they were to be able to do

that successfully, it does not address the core makers and their facilities. Also, it is not enough for a market that is increasing due to increased loading.

4. A fourth major issue is that Proterial is not a US-based company. It is headquartered in Tokyo, Japan. By shutting down GOES materials for distribution transformers, it kills the only US-based maker of silicon steel, Cleveland Cliffs, which makes GOES for the Transformer industry and NOES for the Motor industry.

5. A fifth major issue is multiple sources of supply. Today, GOES are available from Cleveland Cliffs and other magnetic steel suppliers around the world. If the NOPR is implemented as is, GOES would not be able to effectively participate in most of the ratings in most of the Distribution Transformer market. One glitch and the market would stop. It is imperative that GOES be able to participate by effectively remaining close to current efficiency levels.

6. A sixth major issue is distribution transformer lead times that today are reported out to 36 months. Much of the cause for such long lead times is due to the sophisticated designs that are required to meet the 2016 Regulations and shortages of materials like core steel. If the NOPR efficiencies are implemented, lead times will largely be impacted by amorphous ribbon material as well as core-maker fabrication times. Since the required supply for either ribbon or finished cores is not available today, this critical material would be betting on the unrealistic expectations of facilities upgrades for amorphous related production.

C. DOE Modeling Inaccuracies

1. Selling prices of materials in DOE Optimization model are understated by as much as 40-50%, leading to inaccurate conclusions about best or most economical designs. It appears that most of the designs were not produced recently but were developed in the 2013 timeframe.
2. The ¾ power of kVA that I suggested to the DOE in past rule makings works only over a narrow band of parameters.
    a. The DOE has used it while introducing multiple efficiencies, making it inaccurate over a wider range of efficiencies.
    b. OPS software tries to scale from 1500 kVA liquid filled to 3000, 3750 and 5000 kVA. However our NEMA and Non-NEMA manufacturers, with their own design computer programs cannot find designs, even with:
        i. Exhaustive search optimizing methods that examine all possible combinations of materials and designs. Actual percent winding eddy losses vary as the conductor thickness^4^{th} power. Stray loss is a separate parameter and is normally associated with bus bars passing by iron clamps and tanks. It varies as the current squared. However, the sum of stray and eddy losses can increase the effective winding loss by more than 50% for medium voltage transformers >3,000 kVA, making it impossible to reach the DOE proposed new efficiencies.
        ii. Windings that use copper conductors instead of aluminum.
3. Stray and Eddy losses not accurately determined and applied: OPS software incorrectly shows that Stray and Eddy % losses vary as conductor thickness squared and they do

not attempt to separate into two parts.

4. The OPS Software is only used to perform modeling of a few base kVA ratings, after which scaling is applied to determine other rating efficiencies.
5. Higher kVA ratings are not even able to find designs, even with all copper windings and exhaustive search computer optimization programs.

D. Domestic Core Steel Supplier Out of Business

1. Cleveland Cliffs is currently the only domestic manufacturer of GOES core materials. By the DOE's admission, implementation of the NOPR will mean that GOES materials will not be able to compete with Amorphous cores and will largely be driven out of business. This chart shows well for LV Dry transformers, the core materials that have produced designs as a function of Energy Standard Level. Since LV Dry transformers are proposed in the NOPR to move to TSL 5, the only core materials that can comply use amorphous cores:

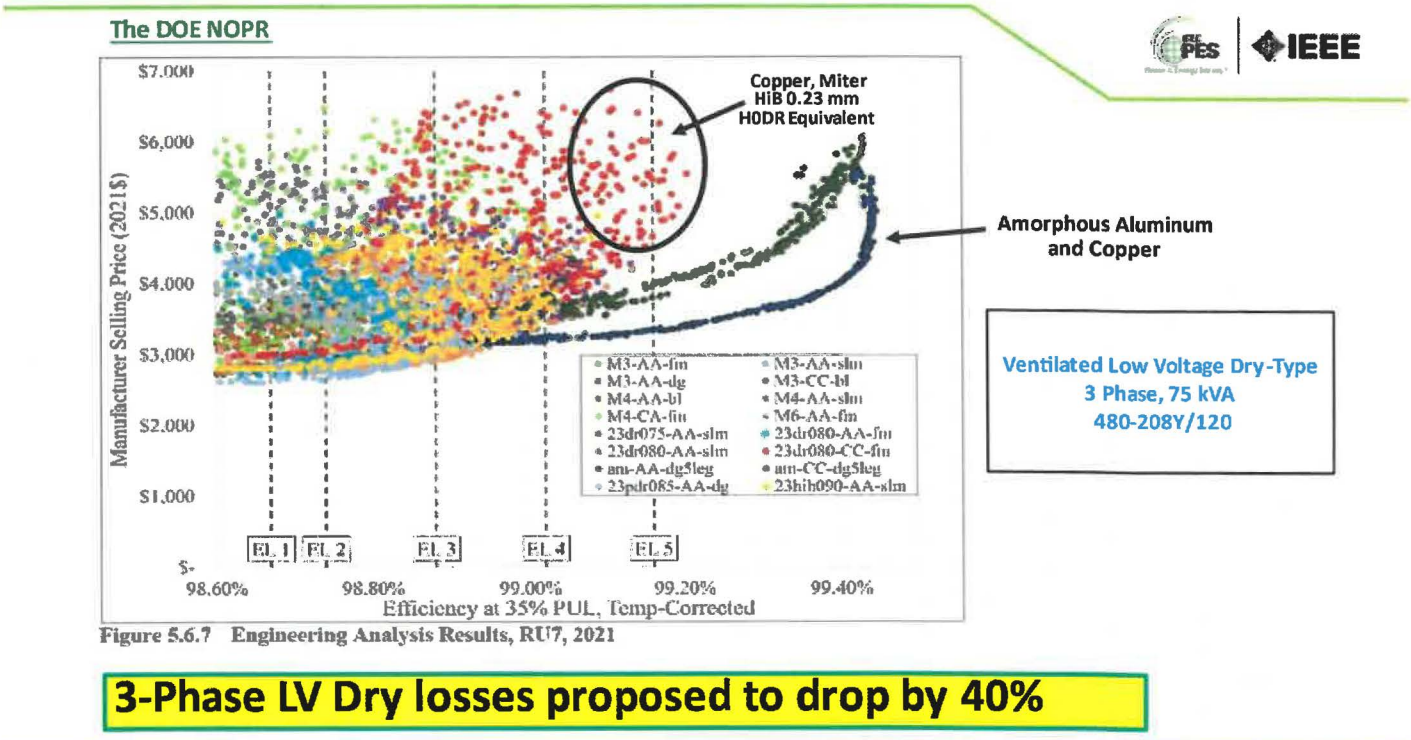


Figure 5.6.7 Engineering Analysis Results, RU7, 2021

Figure 5 shows the DOE scatter plot of usable core materials versus efficiency levels.

2. Many transformers, liquid and Dry, need to be composed of stacked core construction, which is only viable with GOES materials. Amorphous cores must be in wound core construction. When wound cores are used, single phase transformers, will normally be of Core-Form construction with one core loop and two windings (one on each core leg). Three phase construction is best done as (3) single phase transformers in a Tri-Plex configuration. This will generally significantly increase the size of 3-phase transformers. Power Center Dry Type transformers are regularly used in large Lineups. They cannot tolerate changes in physical size increases without widespread disruption.

Summary:

Each manufacturer of distribution transformers has reported similar findings about the NOPR. Categorically, they find it:

1. Devoid of consideration for large loading increases that are starting to show up as in figures 2 and 3 of this report.
2. Capricious in the product types that will be asked for reductions in losses per figure 1.
3. Unwisely basing new efficiency mandates on amorphous material that reaches peak efficiency at 20% of nameplate kVA instead of GOES that reaches peak efficiency at 50% of rated kVA. to reduce core loss when load loss is most important for the load growth that is already emerging.
4. Unwisely choosing to force the industry to convert from GOES that is available in the industry from multiple suppliers to amorphous that is not available in adequate quantities and comes from foreign suppliers.
5. Betting that amorphous will be able to scale up from approximately 16,000 metric tons for the domestic market to over 200,000 tons in 3 years.
6. Shutting down the only US supplier of Grain oriented magnetic steel.
7. Projecting design efficiencies using inaccurate software that in actuality cannot be met by any US manufacturer using GOES, and not even with amorphous in all ratings.
8. Ignoring the large kVA products that need to continue to be made with stacked core construction.
9. Besides core material issues, it is apparent that many designs must convert from aluminum to copper. Modest increases in copper are always welcomed. Complete conversion should be staged and brought on gradually and cohesively. This is at a time when copper is in tight supply and not readily available.

Recommendations:

The DOE should relook the engineering analysis and strongly consider the impacts of load growth, material availabilities and lead times. At this point in time, I recommend that this NOPR be placed on hold until the deficiencies in this report are addressed.

I also strongly recommend that the DOE send representatives to the IEEE Transformers Committee and work with the many stakeholders of manufacturers and users to select new efficiencies that will make the industry stronger.

Very truly yours,

Philip J Hopkinson

Philip J Hopkinson, PE
President & CEO HVOLT Inc.