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ONLINE VIA: https://www.regulations.gov/

Mr. Jeremy Dommu
US Department of Energy
Buildings Technologies Office EE–5B
1000 Independence Avenue SW
Washington, DC
20585–0121

Re: NEMA Comments on Request for Information: Test Procedures for Distribution Transformers

Docket Number: EERE-2017-BT-TP-0055
Regulatory Information Number: None Assigned

Dear Mr. Dommu,

As the leading trade association representing the manufacturers of electrical and medical imaging equipment, the National Electrical Manufacturers Association (NEMA) provides the attached comments on the Department of Energy Request for Information regarding Test Procedures for Distribution Transformers. These comments are submitted on behalf of NEMA Transformer Section Member companies.

NEMA, founded in 1926 and headquartered in Arlington, Virginia, represents nearly 350 manufacturers of electrical equipment and medical imaging technologies. Our combined industries account for more than 360,000 American jobs and more than 7,000 facilities across the United States. Domestic production exceeds $106 billion per year and exports top $36 billion. Please find our detailed comments attached.

Our Member companies count on your careful consideration and we look forward to an outcome that meets their expectations. If you have any questions on these comments, please contact Alex Boesenberg of NEMA at 703-841-3268 or alex.boesenberg@nema.org.

Sincerely,

Kyle Pitsor

Kyle Pitsor
Vice President, Government Relations
National Electrical Manufacturers Association

NEMA Comments on DOE Request for Information: Test Procedures for Distribution Transformers

Key Recommendations:

1. NEMA believes there is no need for significant revisions to test procedures for distribution transformers. We do make several minor recommendations below with respect to reducing testing burden.
2. There is no need to change Per Unit Loading (PUL) test points, either in percentage or in number.
3. NEMA recommends that DOE relax the Test Procedure temperature requirements for winding temperature and laboratory ambient temperature. The temperature of a unit under test and the ability to manage it can significantly impact the burden of testing, especially if testing requirements were expanded.

DOE Issues:

Issue 1. DOE seeks comment, data, and information regarding initial (first year of service) PUL data for distribution transformers.

NEMA Comment: We address this issue to the best of our ability in our response to Issue 2.

Issue 2. DOE requests input on the initial RMS PUL values presented in section I.B of this RFI. More broadly, DOE requests input on the distribution of PUL values experienced by the population of Issue 3. [STET] transformers of a given category (e.g., specific kVA, phases, application, etc.). Specifically, commenters should specify whether the distributional data they provide represents the first year of service, or the full lifetime.

NEMA Comment: We note several studies cited by the IEEE Transformer Committee[1] indicate particular utilities practice very high loading levels, but there is no evidence that this is common. We point out that during the Environmental Protection Agency's (EPA) consideration of a potential ENERGY STAR® program for Liquid Filled Transformers input was provided by several utilities to show they lightly load their transformers. NEMA Members have also seen utility cost of ownership formulas that support this finding. In the experience of NEMA Members this lighter loading happens mostly in the rural electric market. Taken together the two field cases seem to support the continued use current PUL figures.
We recommend that DOE review the EPA data.

We believe the previous DOE Transformer rulemaking's investigations in typical field loading practices remain relevant and as accurate as is possible given the high variations in field conditions.

Issue 4. DOE seeks comment, data and information regarding the load growth estimate over the life of distribution transformers currently being installed. Specifically, DOE seeks comment, data and information on whether loads will increase over time, and if so, what the annual load growth would be for liquid-immersed, LVDT, and MVDT transformers, respectively.

NEMA Comment: We address this issue to the best of our ability in our response to Issue 2.

[1] http://transformerscommittee.org/

Issue 5. DOE seeks comment, data and information regarding the extent to which efficiency is taken into account in transformer purchasing decisions.

NEMA Comment: Some utility customers, who know their anticipated loading, do seek information from their transformer supplier about whether a transformer can be designed to meet best efficiency at that load point. The answer is that it can be so designed, but the transformer must also meet the current DOE efficiency standard and the two are not necessarily the same. In many cases, the two efficiency points (customer's most efficient design at their typical load vs. DOE efficiency rule requirement) cannot be reconciled in a feasible design or manageable cost and the manufacturer is ultimately required to comply with DOE efficiency standard.

NEMA Members in liquid-filled product categories continue to see specifications (anecdotally in up to 40% of requests) from customers which include Total Owning Cost (ToC) considerations as a way of addressing efficiency in the purchasing decision process. We note that a ToC-based decision process does not guarantee that the resulting design will exceed the current DOE efficiency levels by any appreciable margin, only that the long-term cost of ownership is considered by the customer.

NEMA dry-type transformer manufacturers rarely experience ToC requests unless the customer is a utility (which is rare).

There is a niche market in the low voltage dry-type distribution transformer market for highly efficient transformers (exceeding DOE minimum requirements) that is served primarily by the companies Powersmiths and Power Quality International. The actual size of this market is unknown to NEMA Members.

On the medium voltage dry-type side, efficiency does not appear to be a significant consideration. Price and delivery remain the top considerations in the experience of NEMA Members.

Issue 6. DOE seeks comments, data, and information regarding the appropriateness of the current test procedure requirements with respect to temperature correction. Specifically, DOE requests comment on whether testing at specified ambient conditions or correcting to the same internal temperature is more representative of distribution transformer in-service performance.

NEMA Comment: The highly varied instances of field temperature conditions cannot be practically modeled with respect to their impacts on transformer design and operation. In the end the results are still approximations. The temperature conditions for Test Procedures are mostly useful as a reference point, so products can be fairly compared. Changing the approach for temperature conditions is not an effective tool for the purpose of setting energy conservation standards.

We note that Per Unit Loading (PUL) and temperature are related, so if DOE revises PUL then test temperature should be revisited. However, changing either will eliminate the ability to compare future designs to current designs.

The challenge with any reference temperature is the uncertainty involved in individual designs. No specific reference temperature will necessarily be correct since the performance of specific

product designs varies widely with respect to winding temperature rise as a function of load. For example, transformers with identical ratings from different manufacturers could vary in temperature at the DOE loading point for 35% (LV) or 50% (MV). NEMA members have observed significant differences in temperature rise with LVDT units of identical ratings due to variations in design yet both meet the DOE efficiency at 35% load. Ultimately, maintaining the $75^{O}C$ reference temperature provides consistency and is the best approach given the aforementioned uncertainty.

Issue 7. DOE seeks comments, data, and information regarding how temperature varies with PUL, and how significantly it affects transformer performance over a PUL range. Specifically, under the current internal temperature correction methodology, DOE requests comment on how it could specify the reference temperature for testing at PULs other than the current test PUL.

NEMA Comment: The internal temperature of a transformer is driven by two factors: (1) the electrical losses in the transformer and (2) the effectiveness of the cooling system that dissipates the heat from the transformer into the ambient. The effectiveness of a transformer's cooling system is influenced by the temperature difference that exists between the transformer and ambient conditions where it is installed, making it almost impossible to accurately predict the in-service internal temperature of the great variety of transformer designs that exist.

In addition to the challenge of predicting ambient temperature during operation and designing to it, the effectiveness of the cooling system of a transformer will also depend on the configuration of cooling ducts considered during the design phase. These ducts affect more than cooling. The configuration of the ducts and their location in the transformer's geometry impact every aspect of the transformer's performance, to include resistance, impedance, efficiency, temperature rise, physical size, inrush, manufacturing restrictions, and more. Because of these interdependent characteristics, there is a substantial diversity of designs with very different internal temperatures among them even within the same kVA rating. This topic could be studied but to the knowledge of NEMA Member experts there is no known method capable of organizing these interrelated influences into a clear relationship between temperature and PUL for the purpose of energy efficiency testing methods.

That said, there is a well-understood relationship between the PUL and the reference temperature. If DOE decides to change PUL requirements then DOE must also revise temperature requirements. However, there is no way to ensure such revisions would actually result in more efficient transformers because of the reasons described above. Since the internal in-service temperature greatly varies among designs, any calculated improvement would be questionable and will not likely reflect the actual performance of the transformer. This problem is greatly magnified when dealing with multiple PULs as the heat transfer from the transformer to the ambient depends on the delta between its temperatures, increasing the potential error associated with the assumed reference temperature at higher PULs.

NEMA believes the current test procedure requirements for PUL and temperature are adequate, and there is no better method to provide a standard reference for the industry. Modifications to existing requirements would not provide any actual improvement to transformer energy efficiency, but would cause the existing body of test data to become obsolete and historic product performance comparisons no longer possible. Modifications of existing internal temperature correction methodology and PUL testing requirements would saddle manufacturers with significant burden. NEMA strongly recommends DOE keep using the existing method.

Issue 8. DOE seeks comments, data, and information on the continued use of a single test PUL requirement. Further, if a single test PUL requirement is maintained, DOE seeks comment on whether the existing single test PUL requirements should be maintained or whether alternate single test PUL requirements may better match the typical or RMS value in service. In addition, DOE seeks comment on the testing burden using an alternate single test PUL as compared to the current test procedure.

NEMA Comment: As defined on all applicable industry test procedures, transformers are physically tested at 100% load and follow-on test points are calculated. This test procedure/practice should be maintained.

Due to the complex relationship of its electromagnetic fields, the losses on a transformer do not have a linear relationship with the PUL. Therefore physical testing at other than 100% load will result in notable differences in test results. The existing method is well-proven and well-understood by NEMA members and other stakeholders in the transformer industry as the best system to evaluate transformer performance.

In the case of physical testing at multiple PUL, such testing would result in significant technical challenges to keep winding temperatures managed under test conditions, adding significant complexity to the test procedures and introducing new sources for variation. These unavoidable conditions and their impacts on testing will serve to further increase differences between test results and actual in-service conditions. Because of these challenges, testing at one load point is the most feasible method.

It is a well-known fact transformers are rarely operating at a constant PUL. Furthermore, transformers are designed to meet not only efficiency requirements but multiple challenges that must be satisfied like impedance, temperature, manufacturing restrictions and material availability; as a result of these constrictions transformers must be over-designed to ensure they meet DOE minimum efficiencies, satisfy customer demands and overcome design challenges.

NEMA is aware of proposals encouraging the restriction of losses at high PULs, however these proposals are based on very simplistic assumptions that do not consider the real life restrictions a design must meet. Assumptions that a design can be optimized to have the peak efficiency at exactly the wanted PUL and that the load losses can be indefinitely increased through greater use of low-loss materials like amorphous metal do not adequately consider other restrictions transformers have in real life, for example the capacity of the cooling system.

With the above in mind, NEMA strongly recommends DOE not change PUL requirements in current standards as there is no evidence the change will result in a more efficient distribution system.

Issue 9. DOE seeks comments, data, and information regarding testing a single transformer at multiple PULs. Specifically, DOE seeks comment on the degree to which a multiple-PUL weighted-average efficiency would more accurately reflect distribution transformer operation in service, as compared to the current test procedure. In addition, DOE seeks comment on any additional testing burden that might be associated with testing at multiple PULs.

NEMA Comment: As noted above, any other loading level testing is just another calculation. To use weighted average loading to justify higher minimum efficiency levels could be construed as

mathematical trickery. A weighted average formula requirement could also deny a customer who is certain of their field loading level from buying the most efficient transformer for their application. Taken at face value, 50% (or 35%) PUL is an average of sorts, and it allows for sufficient flexibility in field purchasing decisions today whether the resulting design is being optimized for lower or higher loading to suit customer needs.

Issue 10. DOE seeks comments, data, and information regarding the number of PULs (and the corresponding test PUL values) that parties believe may be appropriate for a multiple PUL test procedure. In addition, DOE seeks comments, data, and information regarding what weightings or additional requirements may be necessary under a multiple PUL test procedure.

NEMA Comment: We do not recommend, nor do we have recommendations on, the use of multiple PUL test points or weighted average efficiency methods. See our answer to issues 7, 8 and 9.

Issue 11. DOE seeks comments, data, and information on whether there are any other options or alternative metrics not presented in this RFI that should be considered for measuring and rating the efficiency of distribution transformers.

NEMA Comment: We believe the most appropriate test point for any transformer is its configuration as-shipped, rather than the load point with highest losses as required today. To identify the configuration with highest anticipated losses requires complex calculations and in no way reflects the anticipated field conditions or loading. Both IEEE and NEMA standards, which the DOE references, test a transformer in the as-shipped condition.

It is the belief of NEMA Members that both users and manufacturers recognize that the overwhelming majority of distribution transformers are used in service in the “highest voltage” configuration in field application. While manufacturers will agree that some transformers will have slightly higher losses in the “lowest voltage” configuration, this difference is so small that it is of minimal impact in determining efficiency benefits and the error is much smaller than that introduced by the DOE formula for calculating efficiency. NEMA calculations indicate that typically the difference in losses is less than 1% of the load losses and in no case have we found transformers that are more than 2% higher load loss when tested in “as shipped” versus highest loss configuration, and this slightly higher difference occurs only for a very few voltage configurations. By present DOE distribution transformer efficiency calculations, the load loss for transformers has been reduced by 75% for liquid filled transformers due to Load Factor. It follows that the resulting difference in efficiency between the highest loss and as-shipped configurations is very small, smaller even than the error introduced by the Load Factor correction accuracy used by DOE.

Issue 12. DOE seeks comment regarding the sampling requirements for distribution transformers. Specifically, DOE seeks information on how manufacturers have been applying the sampling provisions. DOE also seeks comments from manufacturers on whether there are instances in which there are questions as to how to apply the sampling requirements or select the appropriate sample size.

NEMA Comment: The selection of sample sizes varies by manufacturer. As such, NEMA cannot respond with a consensus comment to this question and defers to our Members to comment individually.

Issue 13. DOE seeks comment regarding the represented values of efficiency relative to calculated values, specifically, whether manufacturers typically represent the minimum efficiency standard, the maximum represented efficiency (RE) allowable, or a different value; how manufacturers determine what value to represent; and why.

NEMA Comment: As we note in issue 12, the selection of sample sizes varies by manufacturer. As such, NEMA cannot respond with a consensus comment to this question and defers to our Members to comment individually.

Issue 14. DOE's requirements related to AEDMs are at 10 CFR 429.70. This section specifies under which circumstances an AEDM may be developed, validated, and applied to product performance ratings for certain covered products and equipment. AEDM application to distribution transformers is permitted pursuant to 10 CFR 429.47(a)(2) and may serve a manufacturer who finds it burdensome to physically test units of each basic model sold. However, DOE notes that currently, manufacturers frequently test every basic model instead of calculating efficiency using the AEDM provisions.

NEMA Comment: While some manufacturers do test all products, others do not. The opportunity to use AEDM must be preserved, or burden will be raised for some manufacturers. Physical testing post-production is not always at the DOE test conditions (worst case) and is not conducive to mass-production situations. It is NEMA's position that DOE should maintain the status quo and afford manufacturers flexibility.

Issue 15. DOE seeks information regarding the usefulness of the AEDM provisions, and whether and why manufacturers select the option to use AEDMs.

NEMA Comment: This is a business decision. NEMA defers to individual manufacturer members comments on this issue.

Additional DOE requests for comment:

In addition to the issues identified earlier in this document, DOE welcomes comment on any other aspect of the existing test procedures for distribution transformers not already addressed by the specific areas identified in this document.

1. DOE particularly seeks information that would improve the repeatability, reproducibility, and consumer representativeness of the test procedures.

   NEMA Comment: DOE might consider providing software for manufactures that could help with reporting. This could be designed to contain all the raw data and the actual efficiency calculations. NEMA is interested in exploring this further with DOE.

2. DOE also requests information that would help DOE create a procedure that would limit manufacturer test burden through streamlining or simplifying testing requirements.

NEMA Comment: NEMA recommends that the DOE relax the Test Procedure temperature requirements for winding temperature and laboratory ambient temperature. The requirement that lab ambient temperature not change more than $3^{O}C$ in less than three hours and coil temperatures being within $2\ ^{O}C$ of current ambient temperature can be cumbersome in laboratories which are not climate controlled. One method to alleviate this burden might be to develop some sort of correction factor to the tested losses to compensate for potential inaccuracies. In other words, it might be possible to calculate a "worst case" scenario for losses given a certain temperature variation (e.g. add x.x% to losses for each degree Celsius outside the limits). In NEMA Member testing experience, most of the time units pass with enough margin of safety to make the temperature requirement irrelevant. In the preceding comment we are not referring to the temperature requirement in the IEEE test standard, which is more crucial as it relates to temperature rise testing.

3. Comments regarding the repeatability and reproducibility are also welcome.

   NEMA Comment: We have no comment on this issue at this time.

4. DOE also requests feedback on any potential amendments to the existing test procedure that could be considered to address impacts on manufacturers, including small businesses.

   NEMA Comment: We refer DOE to our comments on temperature in item 2 above.

5. Regarding the Federal test method, DOE seeks comment on the degree to which the DOE test procedure should consider and be harmonized with the most recent relevant industry standards for distribution transformers and whether there are any changes to the Federal test method that would provide additional benefits to the public.

   NEMA Comment: We refer DOE to our comments on Issue 11 above.

6. DOE also requests comment on the benefits and burdens of adopting any industry/voluntary consensus-based or other appropriate test procedure, without modification. As discussed, the Federal test method for distribution transformers is based on the industry standard NEMA TP 2-1998. The Federal test method is also based on IEEE C57.12.90–1999 "IEEE Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and IEEE Guide for Short Circuit Testing of Distribution and Power Transformers;" IEEE C57.12.91–2001, "IEEE Standard Test Code for Dry-Type Distribution and Power Transformers;" IEEE C57.12.00–2000, "IEEE Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers;" and IEEE C57.12.01–1998, "IEEE Standard General Requirements for Dry-Type Distribution and Power Transformers Including those with Solid Cast and/or Resin Encapsulated Windings." When establishing the Federal test procedure for distribution transformers, DOE determined that basing the procedure on multiple industry standards, as opposed to adopting an industry test procedure (or procedures) without modification, was necessary to provide the detail and accuracy required for the Federal test procedure, with the additional benefit of providing manufacturers the Federal test procedure in a single reference. 71 FR 24972, 24982.

NEMA Comment: There is benefit to adopting an industry standard but perhaps limit the reference to the actual tested losses and let the method by which efficiency is calculated remain the DOE standards. Accuracy should be assured as transformer manufacturers who participate in the standards process are very careful to make the test procedures as accurate as possible.

7. Additionally, DOE requests comment on whether the existing test procedures limit a manufacturer's ability to provide additional features to consumers on distribution transformers. DOE particularly seeks information on how the test procedures could be amended to reduce the cost of new or additional features and make it more likely that such features are included on distribution transformers.

   NEMA Comment: We refer DOE to our comments to Issue 9 above.