Date Filed: November 03, 2026

Witness: John P. DiPaola-Tromba
Request from: Department of Energy and Environmental Protection

Question:

Refer to Exhibit CLP-TSP-3, pp. 68–70. Please describe how the EPRI Power Transformer Expert System ("PTX") health-index results are used to select and prioritize transformer replacements. Please provide a summary table, by year for 2027–2031, showing the number of transformers proposed for replacement, the applicable health-index range, estimated replacement cost, and any other principal factor supporting replacement. Identify any material instances in which the proposed replacement order differs from the PTX ranking and explain why.

Response:

Eversource employs several methods to both actively and passively monitor the health of distribution power transformers within its service area. Active and continuous monitoring methods include out of specification alarming. Alarms may include indications for bushing monitoring (if applicable), LTC trouble, dissolved gas (if applicable), oil level alarms, and oil temperature alarms, among others.

This information along with periodic maintenance and testing reports provide data into Eversource's condition-based asset management methodology that draws on multiple sources including:

- Transformer nameplate characteristics
- Oil quality and DGA trends
- Abnormal thermal, electrical, or core indicators derived from PTX health modeling
- Maintenance and inspection records
- Power Factor Testing

Eversource utilizes a detailed asset health score generated through the Electric Power Research Institute (EPRI) PTX tool to assess power transformer asset health. OCC-596, Attachment 4 CONFIDENTIAL, is a technical guide to the EPRI Power Transformer Expert System (PTX). The PTX tool evaluates normal degradation, abnormal operating conditions, oil quality, and age to produce two critical indicators: the Long-Term Health Index (LTI) and the Short-Term Health Index (STI). The PTX health index is measured in the range of 0 to 1, with 0 meaning healthy and 1 needing immediate replacement. A value greater than 0.5 is considered poor health, such that if

repair/replacement is not performed the transformer will continue to decline leading to equipment failure.

Eversource has 27 transformers in CT, or about 8.6% of the fleet, that fall within the range considered to be in poor condition. This means that without repair or replacement, their condition is expected to continue declining, increasing the risk of equipment failure. As a result, Eversource continues to prioritize and initiate replacement projects for these transformers.

Prior to initiation of a transformer replacement project, the various subject matter experts (SMEs) will confer and review the nameplate data, maintenance records, and PTX scores of the unit. If a transformer is reviewed and a capital project is not to be initiated, the transformer is typically recommended to have further evaluation for maintenance mitigation of the found issue. This may include repairs or minor refurbishment actions that enable the power transformer to be reenergized and placed back in-service.

If the transformer is identified as requiring a capital project an initial funding is established and a project team assembled. The project team includes various SMEs and they are required to review the technical and financial feasibility of transformer replacement, transformer refurbishment, load transfer options, and usage of existing spare transformer inventory for a replacement. After the feasible options are developed, the project team will proceed with a formal review of the multiple feasible options within the procedures of the Eversource Solution Design Committee.

Using the nameplate data with age and ratings combined with the PTX scores, the power transformers will be identified to proceed with the initial capital project evaluation within the Targeted System Plan. As these evaluations are completed, the power transformers will be prioritized and projects initiated as confirmed. The project sequencing and deferral options will be evaluated within this review.

The average cost of a bulk transformer replacement project is ~$8M per unit. This cost varies with the size of the transformer and any other scope included in the replacement. Examples of other scope to be evaluated include the adjacent switches and breakers, transformer protection relaying and metering, cables and conduits from the transformer to adjacent equipment, etc. These items are evaluated and reviewed within the project approval review cycles. The Targeted System Plan includes an average of 8 bulk and distribution transformers with an investment of ~$78M per year. The exact number will vary each year as the transformers are confirmed to be replaced and the project scopes are developed and approved. A typical transformer replacement can take from 2 to 5 years to plan and execute. From the time of identification of deteriorating health, the transformer will continue to degrade over the course of the project execution time period.

Please refer to the Company's responses to OCC-596[i] and OCC-597[ii] for additional information.

Prior Referenced Responses:

[i] OCC-596 Question:

Refer to Exhibit CLP-TSP-1 at 55, "…plan to maintain a transformer fleet that does not exceed 70 years of age." Identify every law, regulation, manufacturer requirement, or mandatory engineering standard that requires a substation transformer to be retired at 40 years, 70 years, or any other specified age. If no such requirement exists, please confirm.

a. Provide all existing studies, analyses, and historical data relied upon by the Company to conclude that transformer failure risk increases rapidly as transformers approach or exceed 70 years of age. If the Company has not performed an empirical analysis using its transformer-failure experience, please justify.
b. Provide the Company data and analyses used to establish the transformer age thresholds or replacement criteria in the TSP, including the stated 40-year useful life and increased failure risk near 70 years. Include the age and cause of failure for each Company transformer that failed during the period covered by the analysis. If the criteria are not based on the Company's actual failure experience, identify the source on which they are based.

OCC-596 Response:

There are no laws, regulations, manufacturer requirements, or mandatory engineering standards that require substation transformers to be retired at a specific age. The age of a power transformer is one of the most important factors in assessing asset condition. Although actual service life varies widely depending on the manufacturer's design, quality of assembly, materials used, operating history, current operating conditions, and maintenance history, the average expected life for an individual transformer is approximately 40 years according to industry consortiums, and manufacturers. International reliability surveys (i.e., CIGRE) report major failure rates on the order of ~0.3% per transformer-year across large populations, with failure behavior influenced by aging and asset condition. Industry asset-management guidance supports risk-based decision-making that balances failure risk and cost.

Eversource employs several methods to both actively and passively monitor the health of distribution power transformers within its service area. Active and continuous monitoring methods include out of specification alarming. Alarms may include indications for bushing monitoring (if applicable), LTC trouble, dissolved gas (if applicable), oil level alarms, and oil temperature alarms, among others.

This information along with periodic maintenance and testing reports provide data into Eversource's condition-based asset management methodology that draws on multiple sources including:

- Transformer nameplate characteristics
- Oil quality and DGA trends
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Term Health Index (STI). The PTX health index is measured in the range of 0 to 1, with 0 meaning healthy and 1 needing immediate replacement. A value greater than 0.5 is considered poor health, such that if repair/replacement is not performed the transformer will continue to decline leading to equipment failure.
Eversource has 27 transformers in CT, or about 8.6% of the fleet, that fall within the range considered to be in poor condition. This means that without repair or replacement, their condition is expected to continue declining, increasing the risk of equipment failure. As a result, Eversource continues to prioritize and initiate replacement projects for these transformers.

Attachments included note that multiple industry sources discuss aging and failure rates of substation power transformers.

- OCC-596, Attachment 1 CONFIDENTIAL, A2 Cigre Brochure 939 AC Transformer Reliability
- OCC-596, Attachment 2 CONFIDENTIAL, 1013566 Plant Support Engineering Large Transformer End of Expected Life Considerations and the Need for Planning
- OCC-596, Attachment 3, EXEC-2022-001242 - Large Power Transformer Resilience Report 7-10-24
- OCC-596, Attachment 4 CONFIDENTIAL, 3002026877_Power Transformer Expert System (PTX) Software Application Guide_ Introduction to PTX, Overview, Technical Basis and Application Information

Based on industry experience, while transformers can operate beyond their typical design life of 40 years, the risk of failure exponentially increases after 70 years of service life, due to paper insulation degradation. OCC-596, Attachment 1 CONFIDENTIAL, a CIGRE study from 2024, shows the failure rate of transformers has a noticeable increase starting at 40 years and exponentially increases as the asset exceeds 65 years old. This study reviewed analysis of thousands of transformers including many voltage classes from around the world to build depth into the data available. OCC-596, Attachment 2 CONFIDENTIAL is an EPRI paper discussing "Large Transformer End-of-Expected Life" which notes "the useful life of a large, oil-filled transformer is between 30 and 40 years with insulation or bus supports being the most likely to fail due to age. For the insulation, thermal aging of the paper insulation is the likely cause of failure."

OCC-596, Attachment 3, is a Department of Energy report from 2024, citing that large power transformers "are typically considered to have a design lifetime on the order of 40 years. In 2014, a DOE report estimated that the average age of LPTs in the North American grid was 38–40 years, indicating that a substantial fraction of those LPTs are at or over that design lifetime. These LPTs will ultimately need to be replaced or refurbished." These industry research groups and others have provided basis within their published studies to support the concerns of failure with any transformer over 40 years in-service.

As a result, Eversource's Asset Health philosophy for transformers is to operate transformers to their maximum useful life, but plan to maintain a transformer fleet that does not exceed 70 years of age and an average age of approximately 35 years. The objective is to find the balance between affordability and preventing an aged transformer fleet that approaches the "knee of the curve" which results in failure rates that increase significantly. With a large portion of the transformer fleet being between 50 and 80 years old, as these transformers continue to approach and exceed 70 years, the rate of failure will increase rapidly. Due to the complexity and time duration of procuring and replacing transformers, a significant increase in failures would result in the inability to maintain reliability by reactively replacing an increased volume of transformer failures.

The six most recent failures of transformers in CT were all attributed to internal failures of the transformer. The ages of the failed transformers were 32, 50, 52, 52, 56, and 83 years old at the time of the failure.

[ii] OCC-597 Question:

Refer to Exhibit CLP-TSP-1 at 55. For each proposed proactive replacement, identify whether the Company evaluated continued operation through enhanced inspection, testing, monitoring, maintenance, refurbishment, loading limits, load transfer, or use of a spare transformer. Provide each existing analysis and state whether it found that replacement could be deferred by one, three, or five years. If no deferral or life-extension or alternate analysis was performed, please confirm the reason.

OCC-597 Response:

Eversource employs several methods to both actively and passively monitor the health of all power transformers within its service area. Active and continuous monitoring methods include out-of-specification alarming. Remote alarming (if applicable) is conducted through the Eversource SCADA system with alarms existing for bushing monitoring, LTC trouble, dissolved gas, oil level alarms, and oil temperature alarms, among others. Per industry best practices, local alarming is performed through panel indication lamps with corresponding nameplate alarm descriptions and annunciation technologies such as bulb annunciators and Human Machine Interfaces (HMI's).

The preventive maintenance procedures for power transformers are documented within the Eversource Maintenance Program (EMP) 5.58 Station Transformers and Oil-Filled Shunt Reactors. The inspection and maintenance tasks are catalogued into three (3) categories which include a list of asset conditions for real-time condition monitoring, time-based regular inspections, and condition-based maintenance activities. These are described in more detail below:

Condition Monitoring: Various parameters related to power transformer health are actively monitored as applicable. The monitoring is performed both locally and remotely with local monitoring performed by individual equipment alarms and station annunciators. Remote monitoring is performed via Supervisory Control and Data Acquisition (SCADA) to enable real-time asset parameter output and SCADA equipment alarms. Such parameters include temperature, oil level, pressure, and load tap changer (LTC) status.

Time-Directed Maintenance and Inspections: Eversource has established multiple routine maintenance activities required to be performed for all power transformers within specific time intervals. These activities include monthly visual inspections, annual oil sampling including dissolved gas analysis (DGA), thermographic readings, LTC maintenance, and major maintenance activities. Major maintenance activities include power factor testing, bushing testing, excitation testing, confirmation of proper operation and integrity of pressure relief devices and ensuring all alarms operate properly.

Condition-Based Maintenance: These activities are on an as-needed basis when identified upon visual inspection, when performing time-directed maintenance activities, and when output from condition monitoring devices indicate outside normal operating values. Such activities include, but are not limited to, acoustic measurements, core grounding tests, leak repairs, and chassis repair.

Substation Technical Engineering leverages data collected by the CASCADE, PTX Analysis, and substation equipment databases to perform asset condition assessments of power transformers. The reports are based on the following six (6) parameters with recommendations for replacement by the Substation Technical Engineering team being based upon whether two (2) of the following

(6) parameters are considered high risk:

- Oil Analysis Results
    - DGA
    - Fluid Quality Analysis
    - Furan Analysis on Main Tanks
- Age

- Loading
- Maintenance History
- Historical Test Data
- Physical Inspection Findings

The above practices are applicable to all power transformers. Asset age and condition will prompt enhanced inspection, testing, monitoring, and maintenance as noted in the EMP toward the goal of maximizing the usable life of a transformer.

Historically the Company has effectively maximized the life of Transformers by extensive maintenance and monitoring practices, evidenced by the age demographics of the fleet which far exceed the typical design life of 40 years. While this practice continues, the risk profile of an aging fleet compounded by longer lead times and more challenging outage constraints has resulted in a need to initiate planned replacements, beyond the historical average of 1-2 transformer replacements per year, to minimize overall impact of a failed transformer and maximize efficiency. A typical transformer replacement can take from 2 to 5 years to plan and execute. From the time of identification of deteriorating health, the transformer will continue to degrade over the course of the project execution time period. While spares are an effective mitigation plan for emergent failures, it is not a "one-size fits all" long-term mitigation plan to address the fleet risk because depending on when the failure or urgent replacements occur, it may happen at a high-risk period of the year which cannot be controlled exposing the system and customers to a much higher risk. Allowing transformers to run to failure also poses a serious safety risk to both the public and utility workers. Additionally a failed transformer could cause damage to adjacent healthy equipment compounding the negative impact.

Prior to initiation of a transformer replacement project, the various subject matter experts (SMEs) will confer and review the nameplate data, maintenance records, and PTX scores of the unit. If a transformer is reviewed and a capital project is not to be initiated, the transformer is typically recommended to have further evaluation for maintenance mitigation of the found issue. This may include repairs or minor refurbishment actions that enable the power transformer to be reenergized and placed back in-service.

If the transformer is identified as requiring a capital project an initial funding is established and a project team assembled. The project team includes various SMEs and they are required to review the technical and financial feasibility of transformer replacement, transformer refurbishment, load transfer options, and usage of existing spare transformer inventory for a replacement. After the feasible options are developed, the project team will proceed with a formal review of the multiple feasible options within the procedures of the Eversource Solution Design Committee.

Using the nameplate data with age and ratings combined with the PTX scores, the power transformers noted in Exhibit CLP-TSP-1 at 55 have been identified to proceed with the initial capital project evaluation within the Targeted System Plan. As these evaluations are completed, the power transformers will be prioritized and projects initiated as confirmed. The project sequencing and deferral options will be evaluated within this review.

The two active and ongoing projects for transformer replacements included within the Targeted System Plan followed the processes noted above, were prioritized within the project portfolio, and are planned to be placed in-service in 2028.