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POWER SYSTEMS TECHNOLOGY

INSULATION SYSTEMS

OIL, FLUIDS, SOLIDS AND COOLING SYSTEMS

Interview with **Anthony Coker**, Executive Vice President of the Americas at MIDEL
Trent Williams: Understanding Liquid Immersed Power Transformer Cooling Systems
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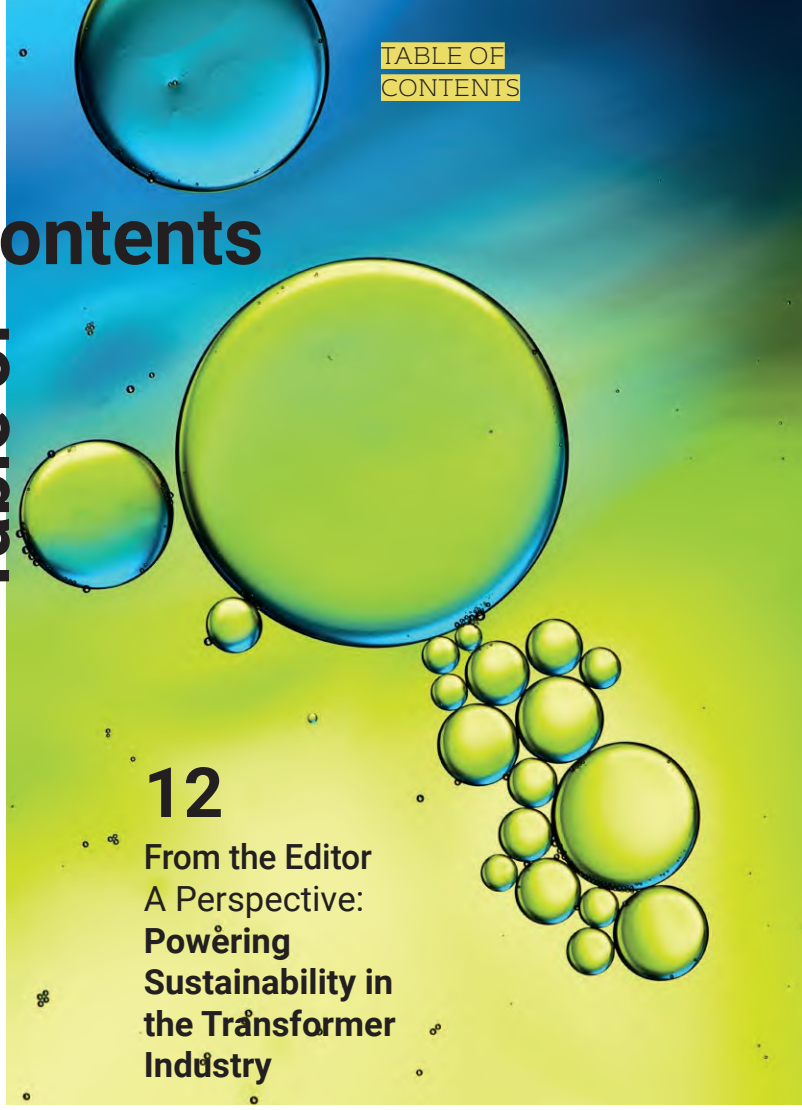

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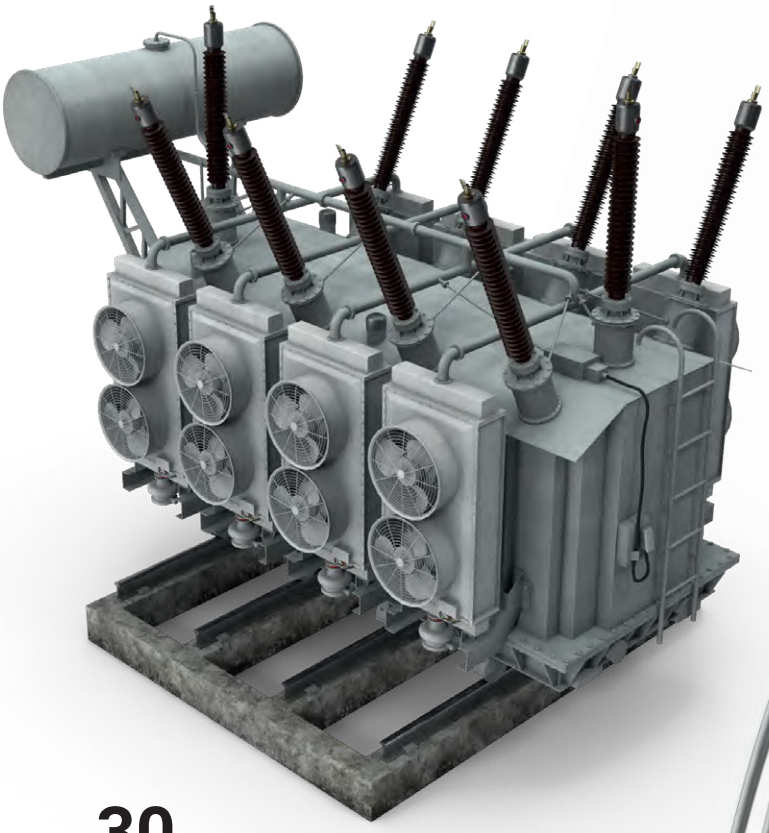

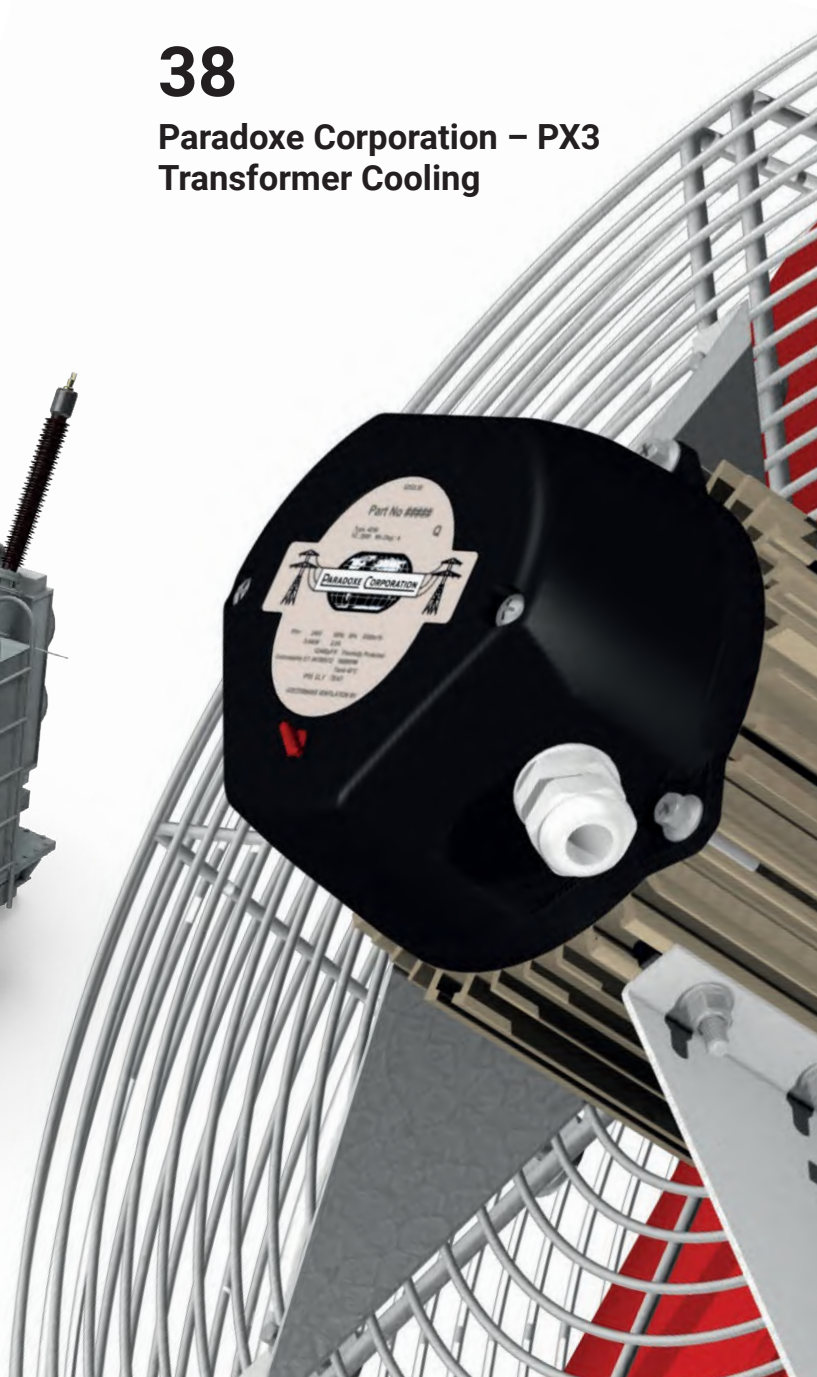

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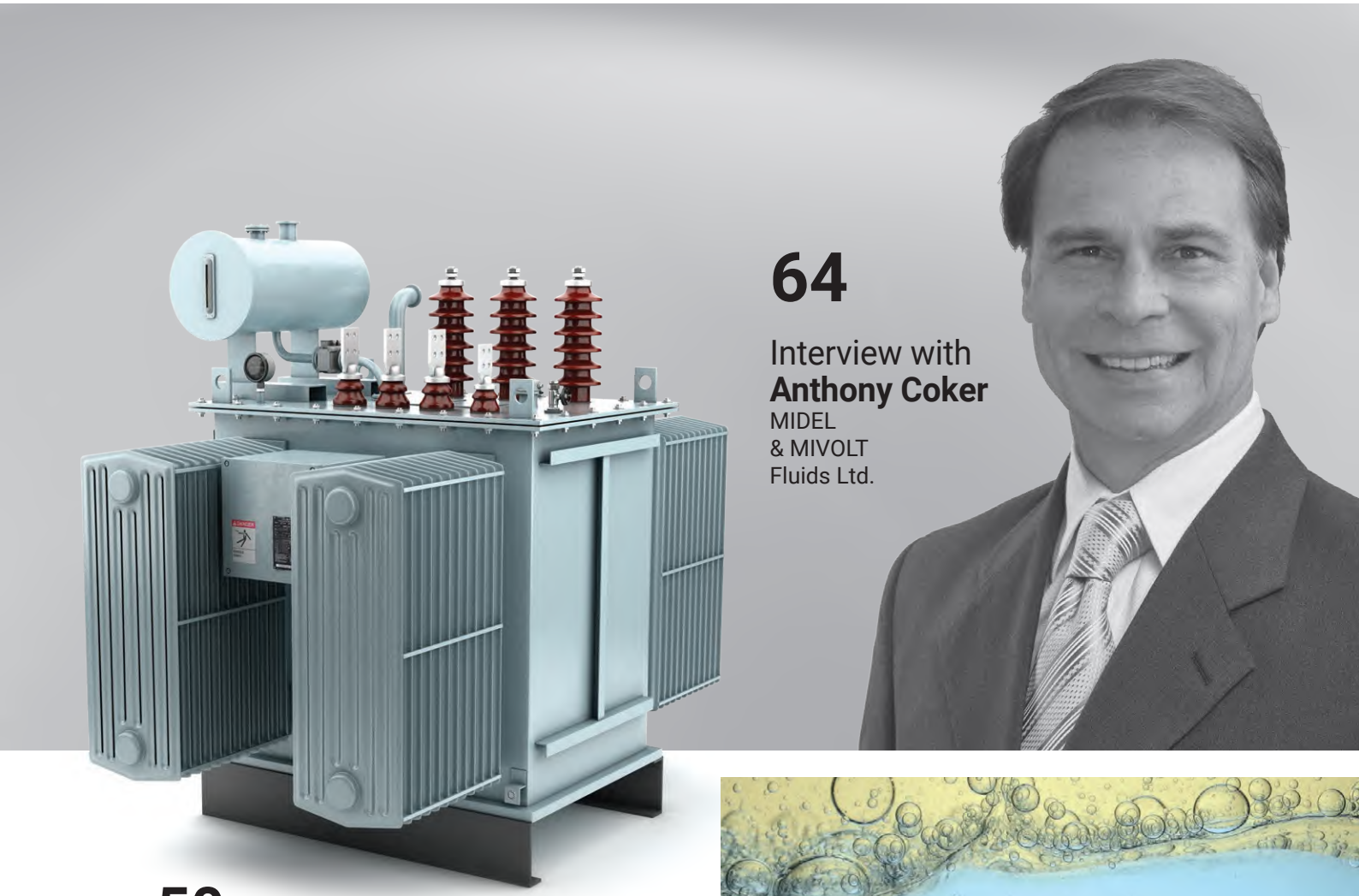

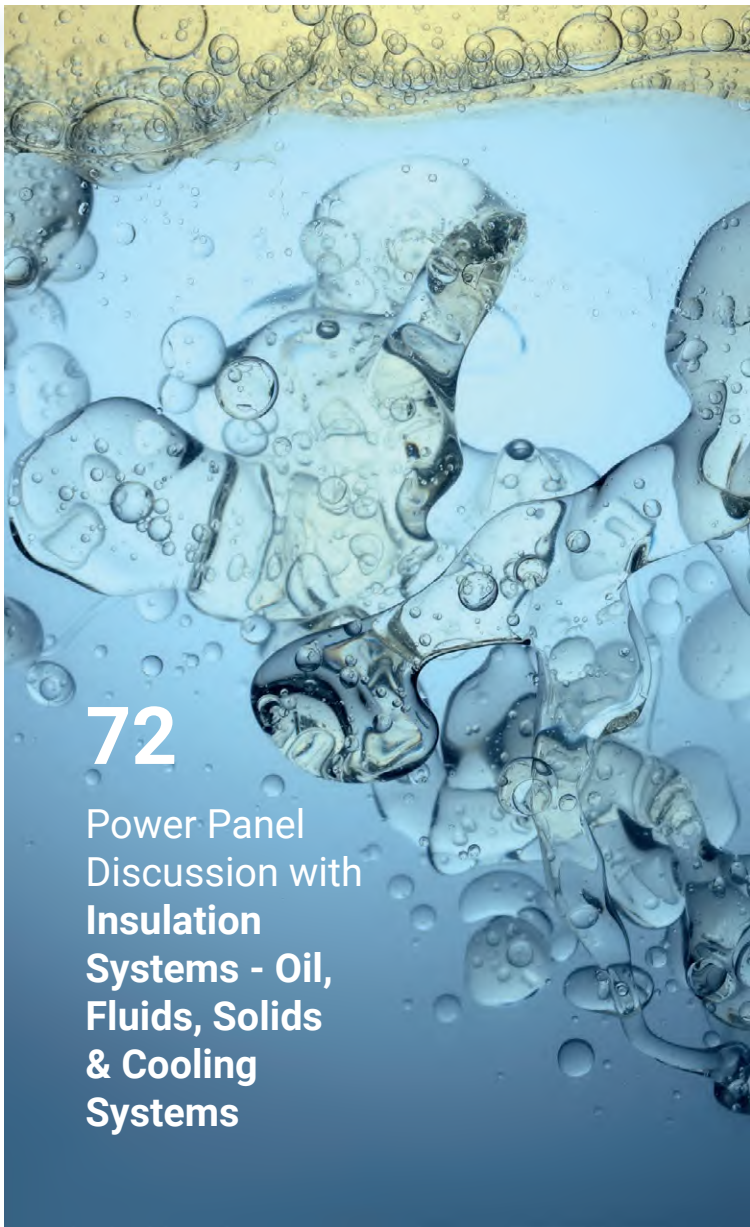

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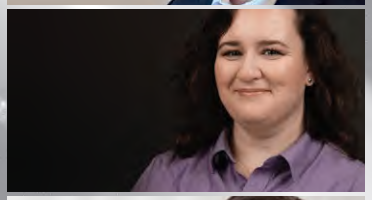

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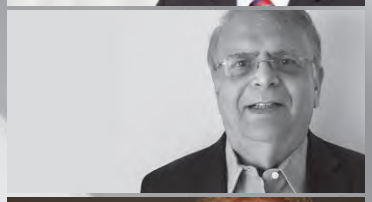

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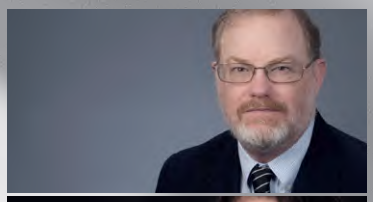

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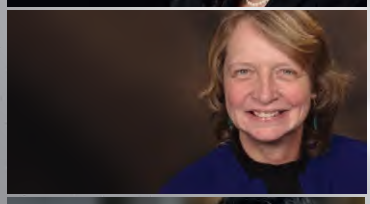

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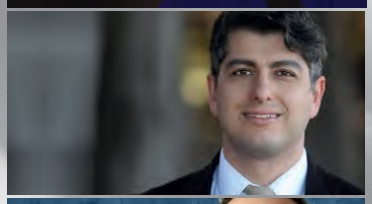

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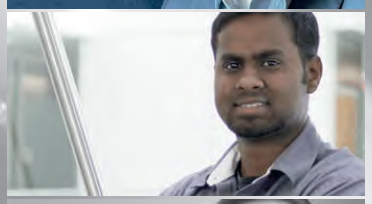

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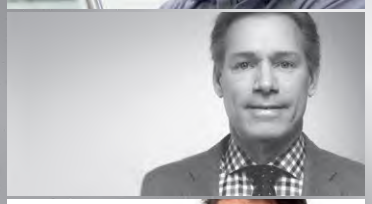

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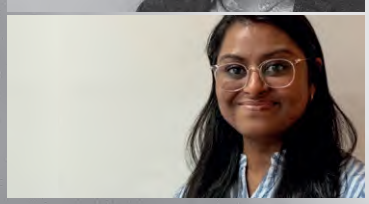

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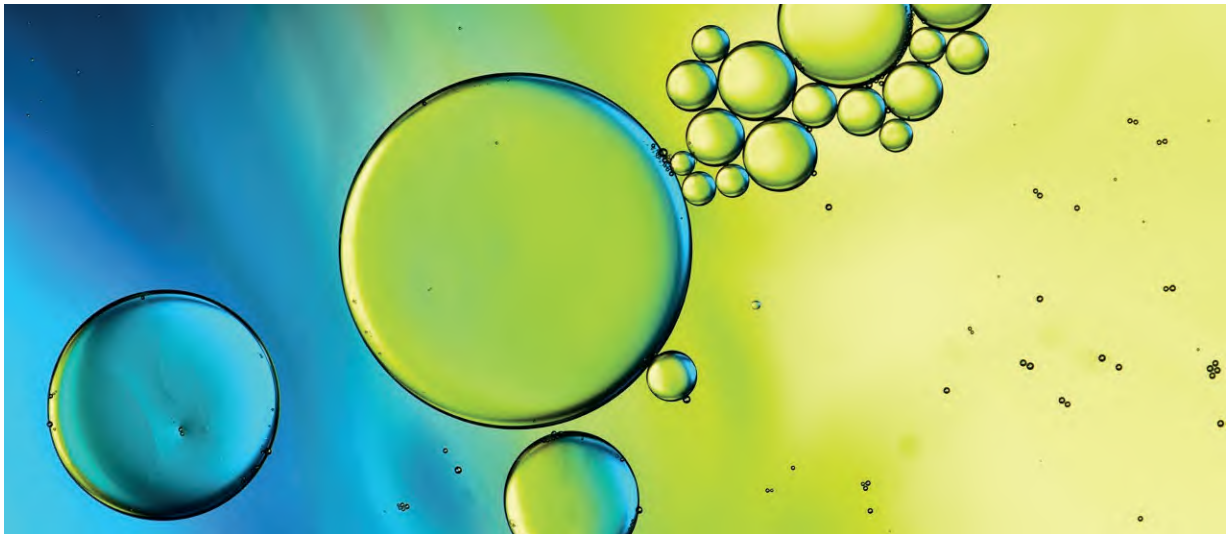
Powering Sustainability in the Transformer Industry

Over the five years we have been publishing Transformer Technology, one of the most downloaded, archived and read issues every year is our annual December Issue on Oils & Fluids. In 2023 we expanded the topic to "Insulation, Oils & Fluids" and this year, a more refined "Insulation Systems, Oils and Fluids".

Given the broad use of mineral oils as the insulating oil of choice for decades, what strikes me most is how fast things are changing, even as it relates to this topic. Insulating papers are getting better, esters are rapidly growing as an alternative to mineral oil, and even that old standard is changing to meet the need for better oils and for decarbonization.

One of the often overlooked yet vital aspects of transformer operation and longevity is the use of oils and fluids. These substances are not merely passive elements; they actively contribute to the performance, safety, and durability of transformers. Let's delve into the significance of transformer oils and fluids, their types, and the emerging trends in this field.

Transformer oils, also known as insulating oils, serve multiple functions. Primarily, they act as electrical insulators, preventing short circuits by providing a high dielectric strength medium. Additionally, they serve as coolants, dissipating the heat generated during transformer operation.



This dual role is crucial for maintaining the transformer's efficiency and preventing overheating, which can lead to catastrophic failures.

Traditionally as mentioned above, mineral oils have been the go-to choice for transformer insulation and cooling. These oils are derived from refined crude oil and have been used for decades due to their excellent dielectric properties and thermal conductivity. However, mineral oils are not without their drawbacks. They are flammable, posing a fire risk, and their environmental impact is significant, given that they are not biodegradable and can cause soil and water contamination in the event of leaks or spills.

In recent years, there has been a growing interest in alternative insulating fluids that address the limitations of mineral oils. One such alternative is synthetic ester fluids. These fluids are engineered to offer superior fire resistance and biodegradability compared to mineral oils. Synthetic esters have a higher flash point, reducing the risk of fire, and they break down more readily in the environment, mitigating the ecological impact of potential leaks. However, they are more expensive than mineral oils, which can be a barrier to widespread adoption.

Another promising alternative is natural ester fluids, often derived from vegetable oils. These fluids are gaining traction due to their excellent environmental profile. They are biodegradable, non-toxic, and have a high fire point, making them a safer and more sustainable option. Natural esters also have good dielectric properties and thermal performance, although they may require more frequent monitoring and maintenance due to their susceptibility to oxidation.

The choice of transformer oil or fluid is not merely a technical decision; it has broader implications for safety, environmental

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sustainability, and operational costs. As the energy sector increasingly prioritizes sustainability, the shift towards more eco-friendly insulating fluids is likely to accelerate. Regulatory frameworks and industry standards are also evolving to support this transition, with organizations like the International Electrotechnical Commission (IEC) and Institute of Electrical and Electronics Engineers (IEEE) updating their guidelines to include alternative fluids.

As the energy sector increasingly prioritizes sustainability, the shift towards more eco-friendly insulating fluids is likely to accelerate. Regulatory frameworks and industry standards are also evolving to support this transition.

Oils and fluids used in transformers are far more than just ancillary components. They are integral to the transformer's performance, safety, and environmental impact. While mineral oils have been the industry standard for many years, the shift towards synthetic and natural ester fluids represents a positive step towards more sustainable and safer transformer operation. As technology advances and economies of scale come into play, the adoption of these alternative fluids is likely to become more widespread, benefiting not just the energy sector but society as a whole.

While mineral oils have been the industry standard for many years, the shift towards synthetic and natural ester fluids represents a positive step towards more sustainable and safer transformer operation.

But even as this trend accelerates, mineral oil suppliers are moving to lower carbon footprints and more specialized applications that esters find challenging to achieve, as ways to maintain their significance in the sector, something that adds to the sustainability argument.

The fact that this is the “theme” we have once again chosen for December 2024 is no surprise, given its importance to transformer reliability, resilience and life cycle management.

Enjoy!

Alan M Ross
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Managing Editor
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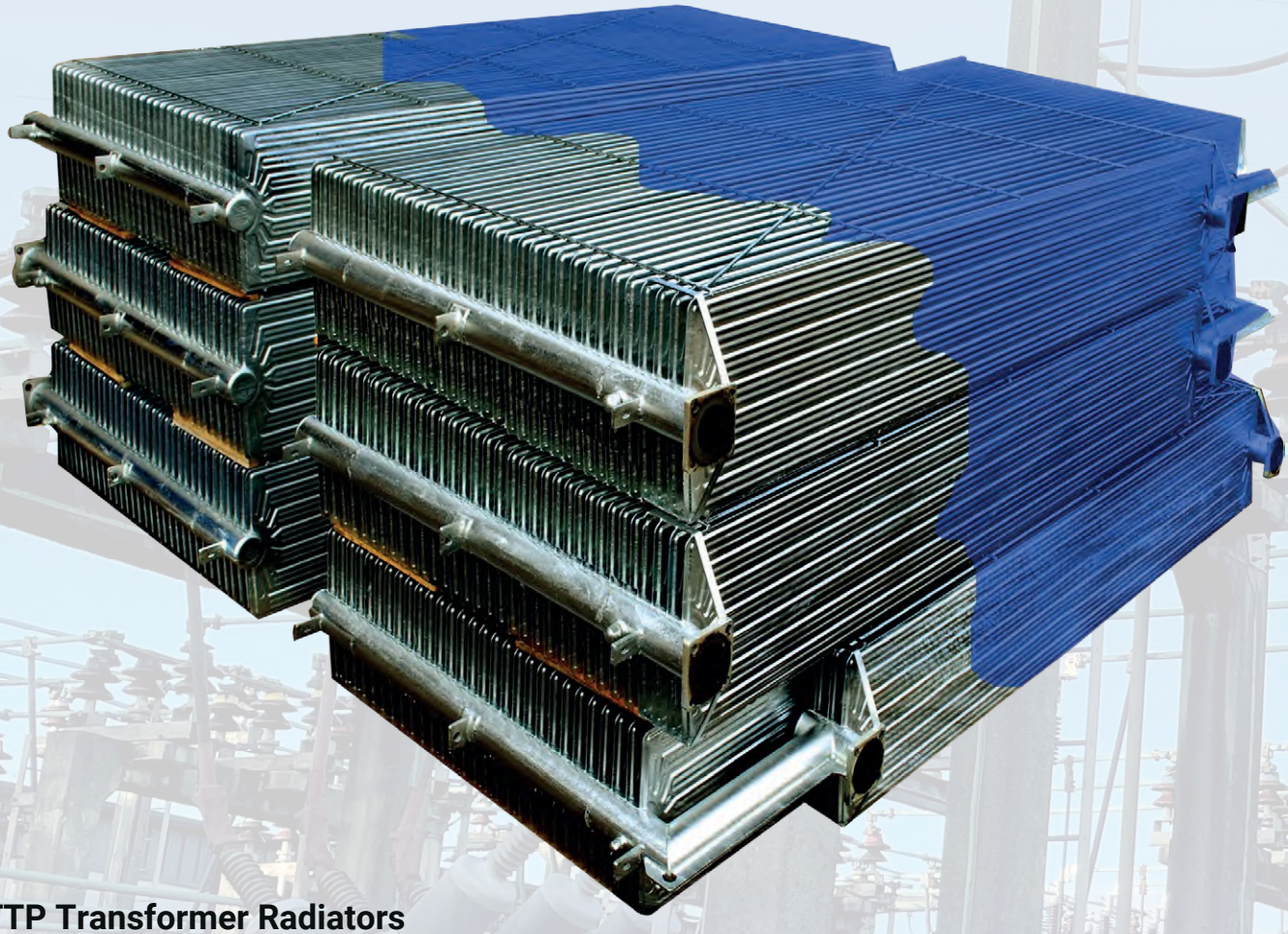

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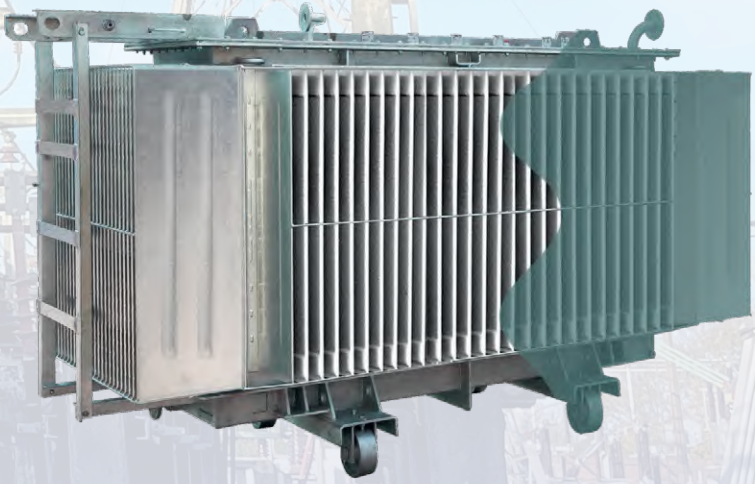

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Randy D. Stebbins, 70 of North Canton, Ohio passed away suddenly on Thursday, December 8th, 2022. He was the loving husband of Linda for 39 years, adored father of Shannon (Josh) Howell and beloved Papa of his granddaughter Riley and grandson Teigen. He is the brother of Wayne (Connie) Stebbins, Danny Stebbins, the late Richard Stebbins (Evelyn) and Roger Stebbins; brother-in-law to Mary Lou and Joseph Simitz, the late Patricia and Wilfred (Butch) Stoehr, and the late Joan and Warren McGuire. He is also survived by many nieces and nephews, great nieces and nephews and great-great nieces and nephews. Randy was born in Barrington, Illinois to the late Riley and Opal Juanita Stebbins on July 6th, 1952. He attended Northern Illinois University in DeKalb earning his Bachelor of Science degree in Chemistry and Physics. He attended the University of Chicago receiving his MBA in Economics and Finance. Randy was employed by S.D. Myers for 29 years first as Laboratory Mgr., appointed Lead Instructor and Technical Advisor for Transformer Maintenance Inc. (EPIQ) before retiring in 2020. In 2021, Randy formed R.D. Stebbins Consulting, LLC. and worked as an Independent Contractor for S.D. Myers. Randy traveled many miles in his position as Instructor over the years to many foreign and domestic locations and most recently again to Australia in October. He traveled to all 50 states doing the work he loved alongside instructors and coworkers that are cherished friends.

Load Tap Changers: Testing Insulating Liquids

by **Randy Stebbins**

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Editor's note:

When I came across this article, first published years ago, written by Randy Stebbins, I realized what an icon he was in our industry, as the Lab Manager and then Training Manager for SDMyers on transformer oil testing, diagnostics and analysis. He taught me more about transformer reliability without ever mentioning the word reliability.

Randy was also an amazing trainer, in that there was not a topic he could not discuss in detail when it came to oil analysis. I remember sitting in for one of his classes and detailed questions, one after another, were all something he could address and do with excellence. Practitioners loved his classes. Sadly, Randy retired and then passed away, but his legacy lives on and I am proud that we at APC Media get to share in that legacy.

Enjoy!

Load Tap Changers (LTCs) are a common feature on many power transformers, designed to automatically change the trans-former's tap position to the desired level. This paper examines the cost-effective and widely recognized maintenance strategy of fluid testing, as outlined by NFPA 70B. It explores the insights fluid testing can provide and highlights key field repairs associated with LTC maintenance. The fluid evaluation process involves several diagnostic tests that help determine the condition of the LTC and inform maintenance actions. A critical factor influencing LTC reliability is liquid oxidation and aging, which can significantly impact performance over time.

HOW DOES OIL AGE IN AN LTC?

Testing the oil in load tap changers provides valuable information on the unit's operation. Monitoring conditions between preventive maintenance inspections is critical in helping prevent expensive main-tenance problems and unplanned outages. The aging mechanisms are considerably different from oil in other electrical equipment types. Understanding this aging process reveals some of the challenges of maintaining LTCs, but it also presents some opportunities for improving the effectiveness of the overall maintenance program.

The interior of an arc-in-oil LTC is a very energetic environment. The oil usually has a relatively high level of dissolved oxygen content since most LTCs are free-breathing. There are two main types of LTCs: the vacuum-interrupter type and the arc-in-oil type.

With the vacuum-interrupter type, the LTC liquid should not have appreciable combustible gases but still has the need for regular liquid testing and maintenance intervals.

There are frequent discharges (arcing) for the arc-in oil type as taps change while under load. Conditions are harsher compared to those inside other types of electrical equipment, which causes one of the aging mechanisms in LTCs -in this environment, oil oxidizes more rapidly than in a milder environment, such as inside a sealed and properly maintained transformer. However, unlike oil in transformers, there is a second aging mechanism for oil in LTCs that affects the operation of the device, usually long before oxidation proceeds far enough to cause any serious degradation of the oil's performance.

As oil ages in a load tap changer, it polymerizes, forming a gummy, varnish-like film over the contacts and mechanism. Viewed with the naked eye, this smooth coating is generally very dark and often mistaken as a carbon deposit or evidence of coking. The smooth appearance is unlike the typical pebbly surface of a coke deposit after it forms in an electrical device. The surfaces of the contacts. that have been wiped clean and show up as bright areas of relatively clean conductor.

This film is both mechanically and electrically resistive. As filming becomes more advanced, it can adversely affect the efficient operation of the device. If the contacts have a heavy layer of film on them, the oil's quenching becomes less effective, so the arc is sustained longer on the contact surface. This may cause hot-spot overheating of the contacts and result in premature wear. In extreme cases, overheating of the contacts may lead to contact failure.

Filming also occurs over the mechanism of the load tap changer, which provides additional resistance to mechanical movement within the device. As a result, the LTC needs to work harder to change taps. It takes longer for tap changes to be accomplished, further extending the

Although oxidation is not generally the most critical aging mechanism of the oil in an LTC, oxidized oil forms film more rapidly than clean, unoxidized oil. Since there is less concern of damage to solid insulation by oil oxidation products in an LTC, the industry has tended to pay less attention to oxidative liquid aging.

The oil inside a Load Tap Changer (LTC) undergoes unique aging processes that can significantly impact the performance of the equipment. Unlike oil in a transformer, which primarily suffers from oxidation, oil in an LTC also forms polymerized films that coat the contacts and internal mechanisms.

Testing the oil in load tap changers provides valuable information concerning whether the unit may have conditions that can create filming at a rate that may compromise the unit's operation. Liquid screen tests, moisture content, and dissolved gas analysis are used to monitor conditions between preventive maintenance inspections and what abnormal results from these tests may indicate.

contacts' arcing. This additional work generally increases the operating temperature within the device due to mechanical resistance. Overheating can become more severe in cases where the mechanism is filmed extensively. Delays in completing tap changes may also cause resistors in the LTC to experience overheating. In extreme cases, the mechanism's operation may be compromised to the point where there is an increased risk of device failure due to binding.

Overheating of the contacts and of the mechanism may also lead to coking. Coking is destructive within an LTC as the hard deposits inhibit proper operation and may lead to contact failure. Also, coke particles are very abrasive to the contact surfaces and may cause premature wear.

Particles from any source, including those caused by the normal wiping of the filmed surfaces during the device's operation, may be incorporated into the film as it forms. These particles are usually very abrasive and generally add mechanical resistance to the mechanism's proper operation.

WHAT CAUSES ACCELERATED FILMING IN AN LTC?

Although oxidation is not generally the most critical aging mechanism of the oil in an LTC, oxidized oil forms film more rapidly than clean, unoxidized oil. Since there is less concern of damage to solid insulation by oil oxidation products in an LTC, the industry has tended to pay less attention to oxidative liquid aging. Most owners use guideline values for acid and interfacial tension that are much less restrictive when evaluating oil in an LTC than those they use for oil in transformers. Our experience indicates that a better strategy is to use the same acceptable, questionable, and unacceptable ranges for values used for in-service oil for transformers. However, recommendations from these values and ranges are interpreted differently than those for transformer oil. In the case of LTCs, replacing or reclaiming the oil is recommended when the values for acid or IFT become unacceptable.

Just as higher moisture content causes oxidative aging of transformer oil to progress more rapidly, elevated moisture content in LTC oil will cause faster filming of the contacts and mechanism. This process is not as clearly defined or documented with LTCs as the effects of higher moisture on the aging of oil in transformers. However, our experience from analyzing particles and filming compounds on oil from load tap changers and reviews conducted during preventive maintenance of such devices confirms a correlation between moisture and filming. Furthermore, high moisture in an LTC also leads to reduced dielectric strength of the oil and moisture tracking within the device. Unacceptable moisture levels indicate an unacceptable risk of tracking and even dielectric failure of the oil. The values we use to define unacceptable moisture levels correspond to those where encountering runaway ilming in the device is expected.

As previously mentioned, film wears off the contacts during the normal operation of the LTC. The movement of the contacts across each other, arcing at the contact surface, and arcing in the oil also produce other types of metallic and non-metallic particles. These particles are incorporated into the new film. If the oil has an unusually high number of particles, or if the particles are unusually large, the new film forms more quickly. Incorporating the existing suspended particles into film as it forms in an LTC can be of particular concern if there are large numbers of metallic or carbon particles. These are much more abrasive than the other non-metallic particles generally found in load tap changers. When film forms on the contact surfaces and incorporates metal and carbon particles, normal operation of the device can erode those contacts at an accelerated rate. Similarly, film incorporating such particles is more mechanically resistive on moving parts of the mechanism, having a further detrimental effect on the efficient mechanical operation of the LTC.

Incompatible compounds in the insulating oil may also greatly accelerate filming in an LTC. One frequent source of such incompatible compounds is using solvents as cleaners during LTC maintenance and inspection to clean the contacts and mechanism. Only hot mineral oil dielectric fluid should be used for this application. Any other material, such as brake cleaner, spot remover, chlorinated or aromatic solvents, or paint or lacquer thinner, may make film removal easier for the current project; however, using these solvents will greatly increase the rate at which the film forms in the future.

Further, films from incompatible compounds may frequently be more difficult to remove. So, the short-term gain from using such cleaners and solvents is far outweighed by the more frequent need to clean the LTC and the greater difficulty in cleaning the device in the future. If an LTC exhibits an unusually severe filming tendency, trouble-shooting oil tests may be performed to help identify the cause. Our experience is that inappropriate cleaning materials account for many of these types of problems.

Testing the oil in load tap changers provides valuable information concerning whether the unit may have conditions that can create filming at a rate that may compromise the unit's operation. These oil tests also indicate other conditions that may require preventive maintenance before normal or planned maintenance. Liquid screen tests, moisture content, and dissolved gas analysis are used to monitor conditions between preventive maintenance inspections and what abnormal results from these tests may indicate.

LIQUID SCREEN TESTS, MOISTURE CONTENT AND DISSOLVED GAS ANALYSIS

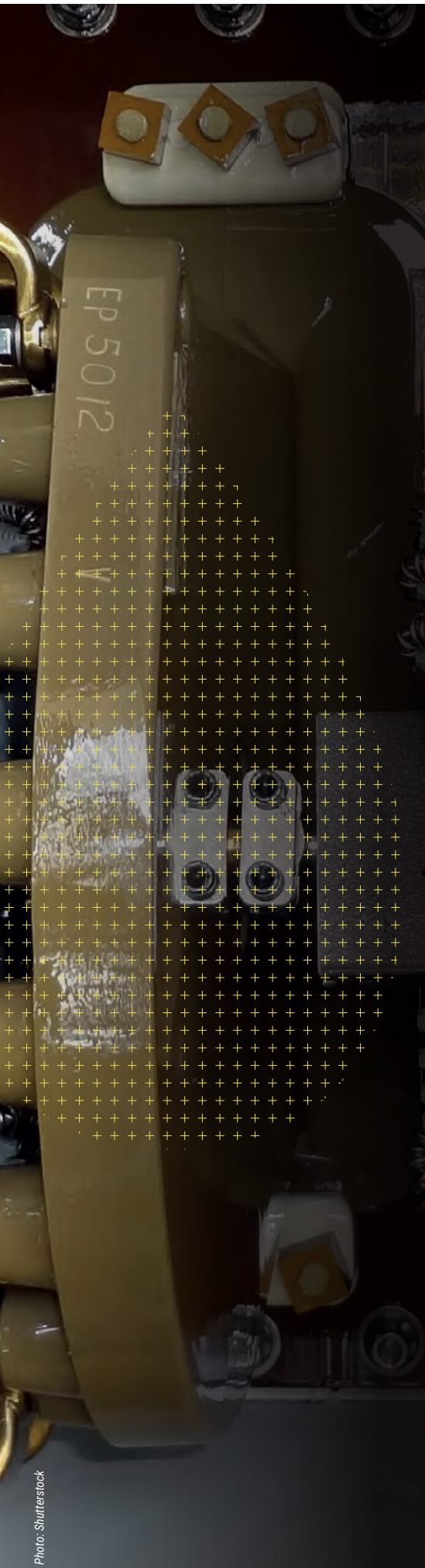
The Liquid Screen test package for LTCs includes the same analyses performed in a Liquid Screen test package for transformers, and diagnostics are conducted for similar reasons. Neutralization number (acid number) and interfacial tension (IFT) are both accurate, direct measures of oil oxidation. The acid number increases while IFT decreases as the oil ages and oxidizes. As discussed earlier, when these values are within the ranges that are classified as unacceptable in a load tap changer, the oil has oxidized to the point where filming starts to advance much more rapidly. The D877 and D1816 Dielectric Breakdown Voltage tests can be valuable tests to detect several contaminants such as very high moisture and particles. Since oil changes in color as it ages, this is usually not quantitative enough to be of diagnostic value on its own. Visual examination for appearance characteristics is much more helpful in evaluating contamination by free water, sediment, and heavily carbonized oil. As with the acid number and IFT, an unacceptable classification for appearance or sediment also indicates a need for corrective action.

Testing for moisture content by coulometric Karl Fischer titration is essential for monitoring the water content of the oil within the load tap changer. Moisture values that are classified as unacceptable indicate a high enough quantity of moisture present to greatly accelerate the filming of the oil onto the contacts and mechanism.

In addition, unacceptable moisture content greatly increases the risks of electrical tracking and even dielectric failure within the device. Unlike typical moisture parameters in transformers—where moisture saturation in the oil and moisture content in the solid insulation present a concern—in LTCs moisture measured simply in parts per million (ppm) is more telling. Moisture content greater than 35 ppm, but less than 60 ppm, warrants increased monitoring via shorter-interval moisture testing (six months). Moisture content confirmed to be 60 ppm or greater indicates need to perform maintenance and reduce the hazards that high moisture presents.

Dissolved Gas Analysis (DGA) has been a valuable tool for evaluating the condition and operation of transformers since the mid-1970s. Using this analysis to evaluate LTCs has a shorter history but is of considerable value for indicating needs for inspection and maintenance. The generation of acetylene and hydrogen is expected as an arc-in-oil load tap changer operates normally. As the LTC changes tap positions, arcs between contacts occur and are quenched by the insulating liquid. These transient arcs form acetylene and hydrogen. Many LTCs have breathers to allow for the escape of the hydrogen—which is not very soluble in insulating oil—to prevent the buildup of explosive conditions in the gas space of the device. If the arc is being quenched efficiently, DGA will indicate increasing values for acetylene. Increases of the other gases should be smaller if the LTC is operating normally.

Abnormal operation of an LTC will cause the unit to have abnormal gassing. The gases of concern are ethylene, ethane, and methane. Ethylene is formed in insulating oil within an energized LTC by temperatures exceeding 300°C, indicating a localized hot spot from sustained arcing and a potential maintenance issue. Under normal conditions—where typical arcing between contacts is occurring and is being quenched promptly—much



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more acetylene than ethylene will be dissolved in the oil. If the arc is sustained for an extended period, the resulting hot spot will generate additional ethylene, and the relative amount of ethylene compared to acetylene will increase. Other abnormal conditions that may cause the generation of ethylene include contacts being poorly aligned so that a smaller surface area on the contact is used to conduct the rated current of the device, resistors (in resistive type LTCs) being overloaded or overheated over their design parameters, and coke formation. Alignment and timing go hand in hand to reduce wear and arcing.

Ethane and methane are also formed under abnormal conditions. When the contacts are overheated by hot spots, ethylene, ethane, and methane are generated and dissolved in the oil in unusually high quantities. Another key factor is the filming of the mechanism of the load tap changer, which causes it to work mechanically harder to continue changing taps. Increased heat is the inevitable result of the additional friction introduced by the buildup of film on the mechanism. Analysis of dissolved gases in oil from LTCs is well established, and industry groups such as IEEE have established guidelines for the interpretation of the gas profiles. Standardizing these guidelines has been challenging because of a lack of universal patterns for abnormal gassing. Different manufacturers—and even different models for the same manufacturer—sometimes have widely differing gas profiles that could all be legitimately characterized as normal. We have assembled an extensive database of test results from different models of load tap changers and have developed a system for diagnosing the conditions within these devices. We have contributed this database to leading industry groups to aid in the collective effort of consolidating technical guidance for LTC owners.

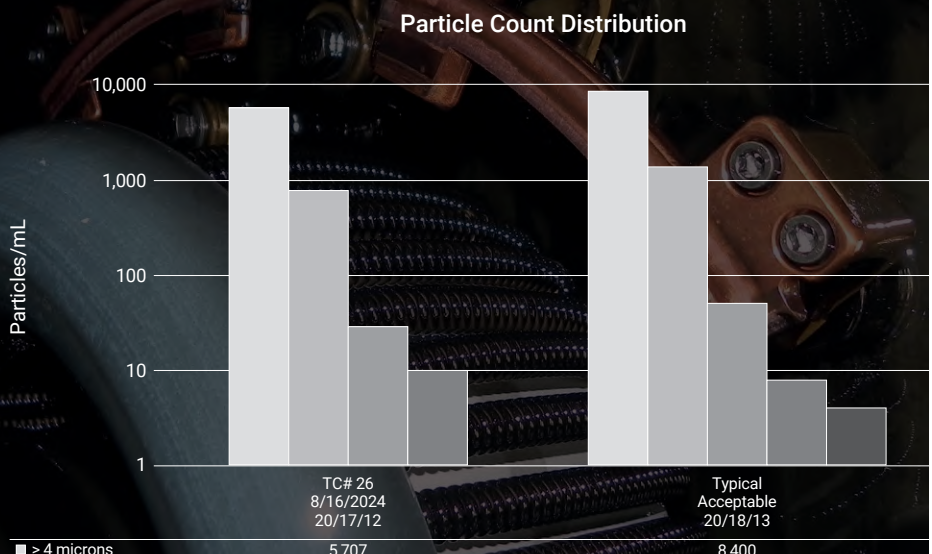
In summary, routine analysis for the Liquid Screen Tests is performed (1) to identify immediately hazardous conditions arising from contamination and other key problems and (2) to evaluate whether the potential for rapidly worsening filming exists due to the condition of the service-aged oil. Moisture content determination evaluates the risks for accelerated filming and, thus, increased risks of dielectric failure or moisture tracking. Dissolved Gas Analysis helps evaluate whether overheating of the contacts or the mechanism indicates abnormal operation. Abnormal results for any of these tests may indicate a need for preventive maintenance and an internal device inspection.

PARTICLE COUNT DISTRIBUTION

We have addressed some of the tests that are routinely performed on insulating liquid from load tap changers: Liquid Screen, Moisture Content, and Dissolved Gas Analysis. Routine testing for the particles found in the oil also provides critically important information. Particles and Filming Compounds Analysis includes two separate analyses: particle count distribution and analytical ferrography. This segment focuses on particle count distribution for load tap changer insulating liquid samples.

Particle counting—total count and size distribution—is performed according to ASTM Standard Method D6786. The automatic particle counter optically senses and then analyzes a test specimen of insulating liquid. It counts and assigns standard sizes to a representative group of particles. The total number of each size in each volume of oil is calculated, and the values are reported as size distribution in particles per milliliter for each size range. Older or non-standard methods may have reported particles per 10 mL or 100 mL, and this change in the reporting method must be considered when evaluating history.

Particle count distribution results are reported graphically, like this example:



	TC# 26 8/16/2024 20/17/12	Typical Acceptable 20/18/13
> 4 microns	5,707	8,400
> 6 microns	771	1,400
> 14 microns	29	50
> 21 microns	10	8
> 38 microns	1	4

The graphic above is from analyzing an oil sample from a load tap changer. Below the TC identification and sample draw date, the results are characterized by a rating of the distribution according to ISO Method 4406. Although developed primarily for applications involving lubricating oils, the ISO ratings can be easily adapted for insulating oil applications and are discussed in the ASTM standard method. The rating's first (and largest) value is based on the number of particles per milliliter larger than 4 µm (µm is listed as microns in the data table). Similarly, the middle value is based on the number of particles per milliliter larger than 6 µm, and the last (and smallest) value is based on the number of particles per milliliter larger than 14 µm.

The right part of the graphic indicates what a typical particle count distribution for a load tap changer should be—one that is considered acceptable for an arc-in-oil device. If the values for > 6 microns and > 14 microns are within the appropriate typical ranges, elevated or high values for > 4 microns are usually of little concern. However, high values for the larger size ranges, > 21 microns and > 38 microns, are generally of greater concern. In addition to this base outline, changes since the last analysis and trends upward also affect the interpretation of particle count data.

The most significant source of particles suspended in the insulating oil of an LTC is the filming of the oil. The film accumulates over time as deposits on the contact surfaces. Under normal operation of the LTC, this deposited material is wiped off and sent into the oil as small particles. These tiny particles stay suspended in the oil until they are reincorporated into a new film as they form in the device.

Another significant source of particles in an LTC is carbon formation in the oil due to the natural arcing that occurs as the contacts change position. Carbon particles are also incorporated into film as the insulating oil ages in the device. During normal operation of an LTC, these small film and carbon particles will be noted primarily in the > 4 microns and > 6 microns values and will generally not cause those values to become excessively high. As filming becomes more advanced, or if the LTC operates much more frequently than usual, values for these two smaller ranges increase. More significantly, much greater values for the larger size ranges are also noted when filming becomes more advanced.

Our laboratory uses our experience and database to evaluate particle count results from insulating oil in electrical equipment. These results were compared to actual field data gathered during LTC servicing for many years. Ranges have been established that we consider typical and acceptable based on particle counts by size range.

Particle count distribution provides valuable information concerning the condition of a load tap changer, particularly the rate at which film is both forming and subsequently being disrupted during the operation of the device. There is also a second powerful tool for characterizing particles found in a load tap changer—analytical ferrography —that describes the composition, and sources of the particles found.

Ferrography is an advanced diagnostic technique used to analyze wear particles suspended in oil. Ferrography can aid in identifying mechanical wear, contamination, and overheating by characterizing particles from the oil, and is interpreted along with particle count data to evaluate conditions inside the LTC and inform maintenance responses.

Remember, the oil inside a Load Tap Changer (LTC) undergoes unique aging processes that can significantly impact the performance of the equipment. Unlike oil in a transformer, which primarily suffers from oxidation, oil in an LTC also forms polymerized films that coat the contacts and internal mechanisms. These films can introduce mechanical and electrical resistance, leading to overheating and premature wear of the contacts. The continuous operation under these conditions not only affects the efficiency of the arc quenching but also creates additional stress on the mechanical components, potentially causing failures. Oxidation leads to several conditions seen in liquid tests that are used to diagnose maintenance needs. The liquid tests lead to extended life and optimized reliability when coupled with regular inspections and following manufacturer recommendations.

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SPECIAL SECTION: DistribuTech 2024

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Mike Beehler, Chief Opportunity Officer
Mike Beehler & Associates

Ben Lanz, Director, Strategy & Development
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> Where I see PDI² has a unique role is that it creates a space for experts, consultants, material suppliers, technology providers, people who've been in the field, have the data, have strong utility relationships, and are willing to share what they have learned to rapidly create a center of knowledge accessible to everyone.
>
> **Ben Lanz**

Mike Beehler: Hey, Ben. It's so good to see you. We're here at DistribuTech 2024 and we thought we'd take a moment to talk a little bit about the Power Delivery Intelligence Initiative. You've been involved in the Power Delivery Intelligence Initiative from the early days, and I've been really fortunate to be involved with you in it. I just wanted to ask you a couple of questions. What is PDI²? And what kinds of things can people look forward to from PDI², both now and in the future?

Ben Lanz: PDI² is an organization of men and women in the industry who have diverse utility industry expertise. We have standards organizations, which by nature tend to move very slowly, and we have other organizations that produce best practice information that is exclusive to the membership. Where I see PDI² has a unique role is that it creates a space for experts, consultants, material suppliers, technology providers, people who've been in the field, have the data, have strong utility relationships, and are willing to share what they have learned to rapidly create a center of knowledge accessible to everyone.

MB It's non-exclusive, because it's supported by companies like yours, OSMOSE, with a wealth of information available to the planners, the engineers, and the data scientists that are trying to make informed decisions about new infrastructure. This is 2024, it is time for new standards. We are spending billions of dollars on T&D overhead and underground lines, and we need to do it the right way. I think there's a lot of members of PDI², OSMOSE included, that have got some great ideas, proven ideas, to bring those costs down, the cost of design, the cost of construction, and the cost of operations and maintenance. Why has IMCORP and now OSMOSE been part of PDI² for all these years? Tell us why you think it's valuable to be a part of this organization.

BL IMCORP and now OSMOSE has a cable reliability consulting and diagnostics, offering that provides detailed, foot-by-foot profiles of underground power cables to detect microscopic defects before they fail. Our service is valuable for both aging assets, operating and maintenance, but also during commissioning.

As we worked with major industry players like Dow, Borealis, and Southwire, we often encounter similar questions from utilities about cable longevity, failure mechanisms, and best practices. OSMOSE'S extensive experience, including hundreds of thousands of cable systems scans and thousands of component dissections, positions us to lead in these areas. We have seen that our data has been invaluable to help create effective best practices and in return the opportunity to network with people who are answering those same questions, some of the biggest names in the industry, like ABB, Quanta, Burns & McDonnel, and some of the equipment component manufacturers, like Okonite, Prysmian and Southwire and Vermeer.

MB I can name a few more, like Condux, Champion Fiberglass, Ditchwitch or Polywater. We have other members, and it makes up a nice team of resident experts in undergrounding.

New proven technologies from PDI² members are currently being put into the specifications for new cable installations. I think it's incumbent upon young civil engineers and electrical engineers, that are building billions of dollars worth of assets, to develop these cable installation and commissioning standards.

You've had your company engaged at PDI² for many years. Why do you keep coming back to PDI²? You see there's value there. Why?

BL We have panel sessions, like the ones at DistribuTech, and those rooms are great to meet prospective clients and utility advisors. We're bringing people together, not only the experts, but also the opportunities, and isn't that what we want for the industry?

MB That's what we want to do. We are at DistribuTech here in Orlando, and we have a good panel today. A couple of the panelists, one was from City of Loveland and had just moved from Fort Collins, which is 80 to 90% underground. and another panelist was from Beaches Energy, and they are 90% underground. These are public power utilities that have been underground for a long time.

There is empirical data out there to support improved reliability with underground. Look at the FERC-1 report, for example, and you will show that investor-owned utilities across America, that must fill out reports for the Federal Energy Regulatory commission, stating for the record that their cost of underground operations and maintenance is lower than cost of overhead. Our panelist agreed. Do a good job installing cable and conduit and set it and forget it. They had cable systems that have lasted for the 44 years that he was personally aware of.

That is a story we want to continue to tell.

BL We are continuing to look for members to grow that dynamic network that we have, as well as utility advisors, folks that

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> New proven technologies from PDI² members are currently being put into the specifications for new cable installations. I think it's incumbent upon young civil engineers and electrical engineers, that are building billions of dollars worth of assets, to develop these cable installation and commissioning standards.
>
> **Mike Beehler**

are engaged with us and that want to tell their story about underground. That's a wealth of information on the website, www.pdi2.org and evolves also on LinkedIn.

MB We appreciate your leadership over the years of PDI², Ben. Thank you very much. It's always a pleasure to see you.

BL It's great to be with you too Mike and thank you for your commitment to the future of our industry.

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Trent Williams is an Applications Engineer at Advanced Power Technologies with 10 years of experience in power transformer monitoring, product application and development. He obtained his BSEE from Wright State University. He is a member of IEEE PES, IEEE Transformer Committee, and technical paper author.

Understanding Liquid Immersed Power Transformer Cooling Systems

by **Trent Williams**

Power transformers are critical components in electrical grids worldwide, facilitating the transmission and distribution of electricity over long distances. These transformers are designed to handle large amounts of electrical power efficiently while minimizing losses. One crucial aspect of their design is the cooling system, which ensures optimal operating temperatures and extends the transformer's lifespan. In this article, we will delve into liquid immersed power transformer cooling systems, exploring their types, mechanisms, and their importance in ensuring reliable electricity supply.

In today's culture we find ourselves in a constant bombardment with the terms "innovative", "ground breaking", "state-of-the art" as we see updates within our respective industries. The power systems industry, being no exception to this, often leaves out the basic concepts regarding the functionality of our major equipment as new personnel come on board, change roles, or continue education and training. Power transformer basics have remained rather constant for many years now, being a critical and very costly asset in today's power system but are rarely associated with the words "innovative" or "state-of-the art". We often treat them as no more than another component on a diagram because a transformer is a transformer after all, right?

Importance of Cooling Systems

Power transformers generate heat during operation due to core losses (eddy currents and hysteresis) and winding losses (resistance in windings). Excessive heat can degrade insulation materials and shorten the transformer's lifespan. Therefore, effective cooling is essential to maintain optimal operating temperatures and ensure reliable performance over the transformer's operational life.

Liquid immersed power transformers are designed in such a way that the core and coil are immersed in a bath of transformer oil. The oil absorbs heat from the core and coil and then dissipates that heat through the tank wall and external cooling systems. Ultimately, the loading capacity of a liquid filled transformer is dependent on the cooling capacity to ensure the transformer temperatures remain within design guidelines.

Common Power Transformer Cooling Types

The simplest form of cooling available in liquid immersed power transformers, this method simply relies on natural convection. This method can be classified in two different categories, but both rely on the same principle. Oil Natural (ON) simply identifies there is no external cooling present, and the oil simply dissipates the heat through the tank wall. Oil Natural/Air Natural (ONAN) includes the additional external cooling which is often the installation of radiators. Via natural convection the hot oil enters the radiators at the top port then falls downward in the radiators as the oil cools from air naturally passing along the radiator. The cooled oil then returns to the bottom of the main tank with a continuous convection cycle as seen in Figure 1.

Natural Cooling (ON or ONAN)

Photo: Advanced Power Technologies

Since this method relies on natural convection, there are no moving parts, noise pollution concerns or energy consumption and minimal maintenance items. But there are limitations, we are restrained by the amount of heat the oil can dissipate naturally which in turn limits the loading capability of the transformer (see Figure 1).

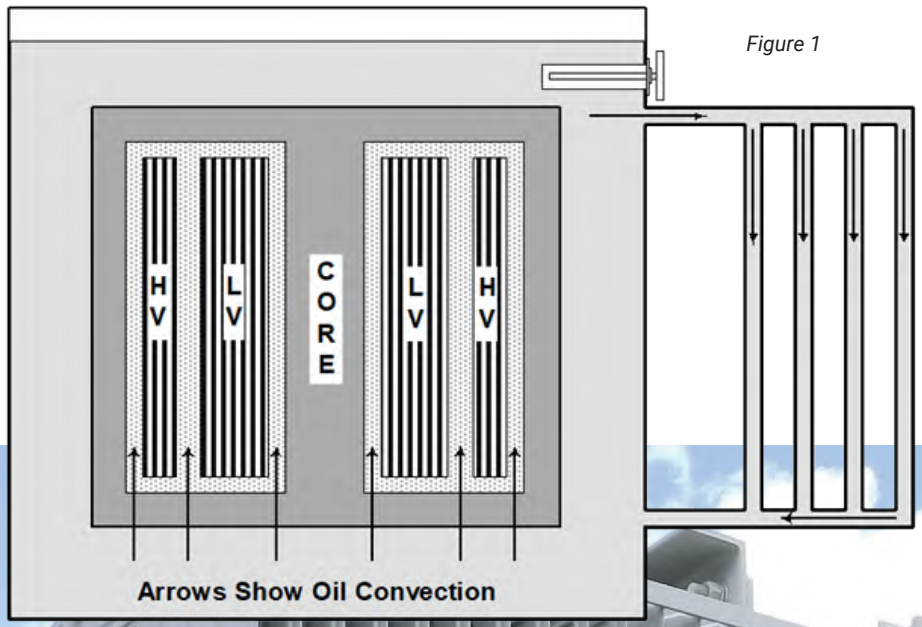


Figure 1

Oil Natural/Air Forced (ONAF)

Very similar to ONAN we have ONAF or Oil Natural, Air Forced which involves the characteristics an ONAN transformer, external radiators, but with the addition of cooling fans which increase the volume of air moving across the radiators' surface therefore increasing the rate at which the radiators can dissipate the heat from the oil which in turn leads to an increase in the transformers thermal and loading capacity (see Figure 2).

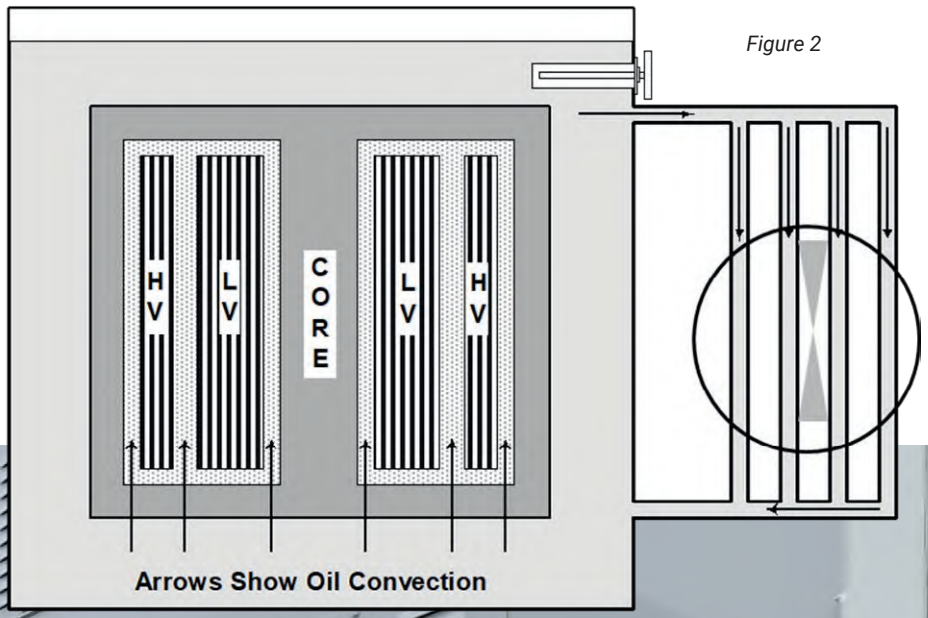


Figure 2

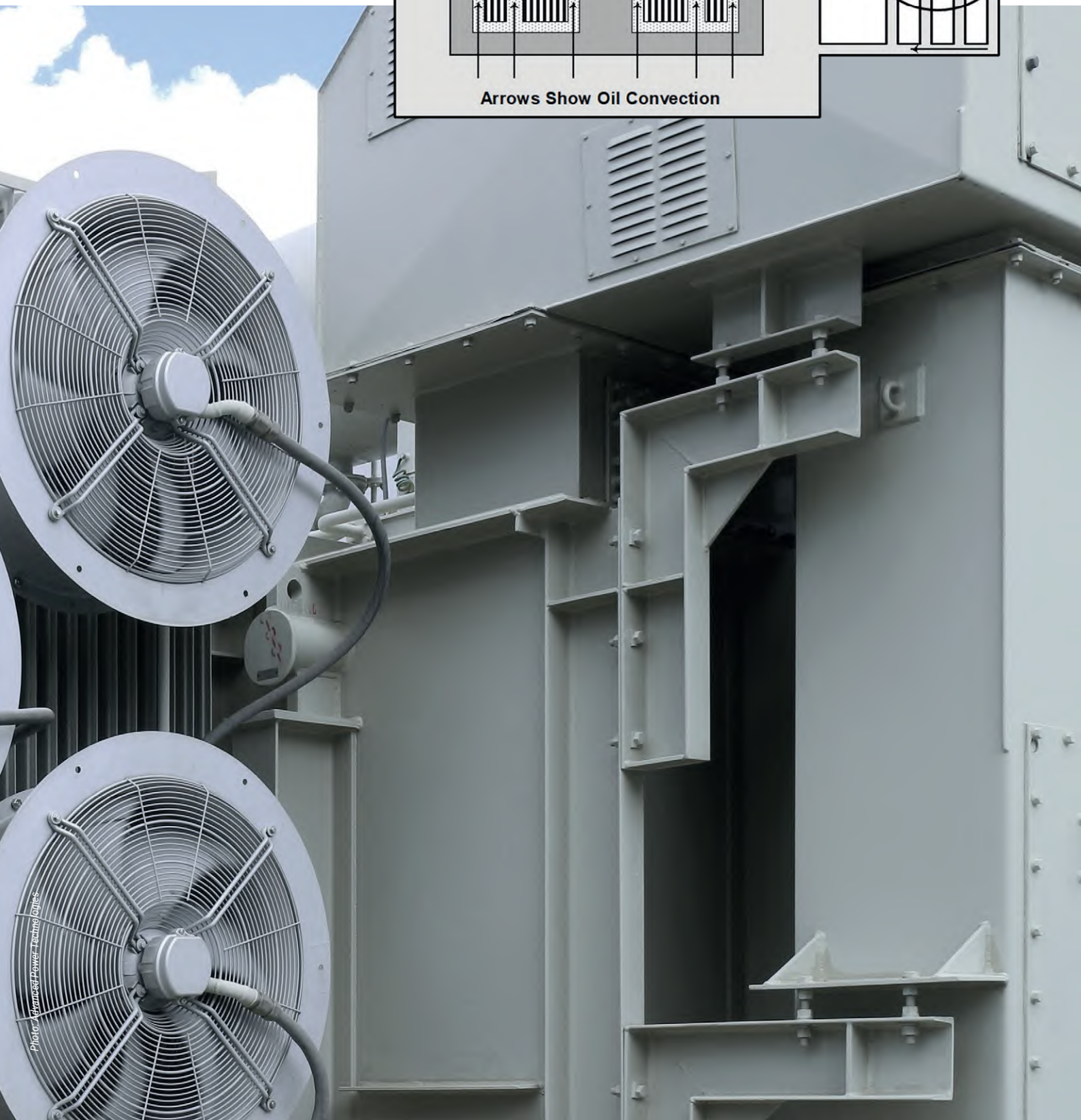


Photo: Advanced Power Technologies

Transformer cooling control systems, sometimes called ETMs, are designed to maintain optimal operating temperatures by precisely regulating the cooling mechanisms. Strategically placed sensors monitor temperatures and other transformer parameters allowing the control system to determine the appropriate cooling response.

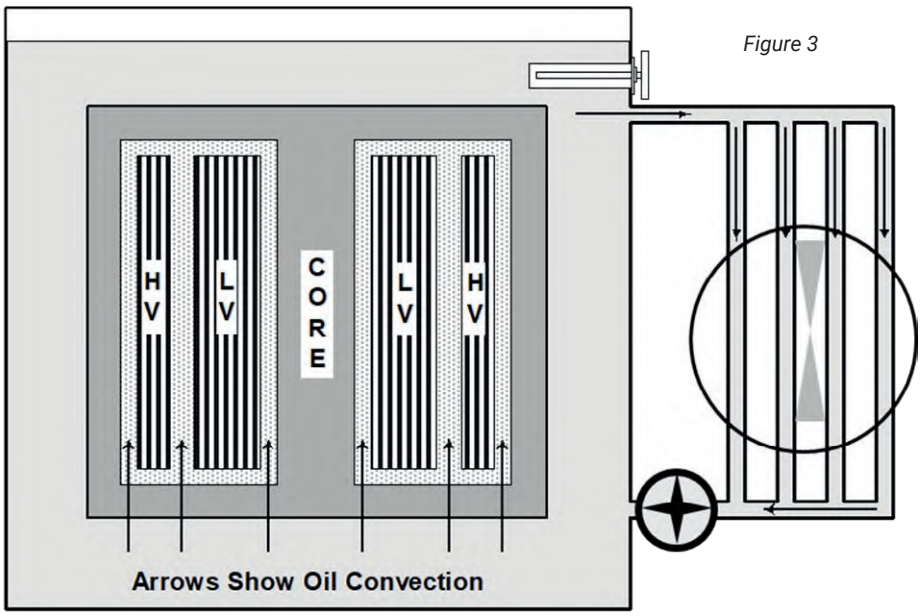
Oil Natural/Air Forced (ONAF)

Photo: Advanced Power Technologies

Oil Forced/Air Forced (OFAF)

Oil Forced, Air Forced, simply building off the two previously described methods with one addition. A pump is added to the cooling system to increase the circulation of oil though the transformer and external cooling system. In some applications of OFAF transformers, coolers are used in place of radiators and fans. These coolers are self-contained units which utilize fans, pumps and radiators to dissipate heat (see Figure 3).

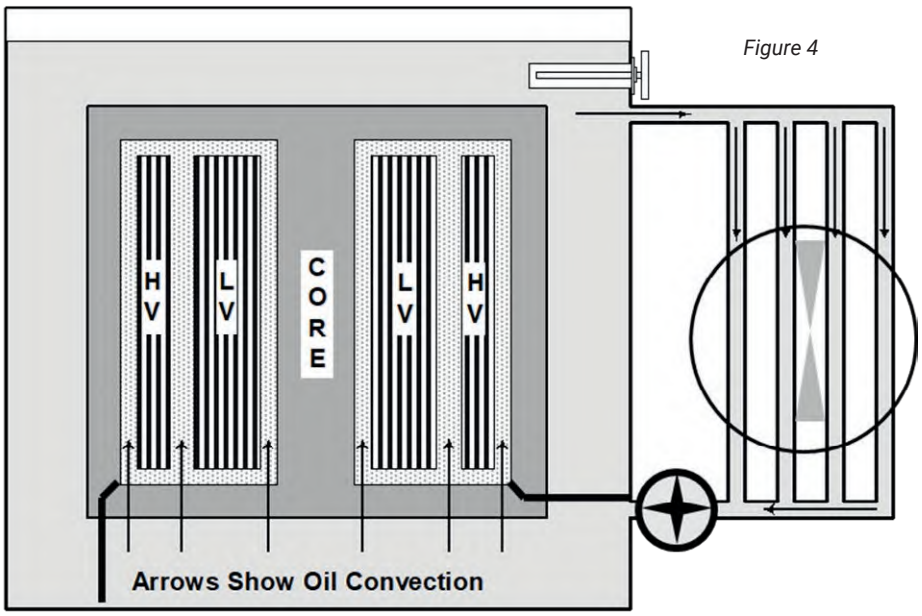
Figure 3



Oil Directed/Air Forced (ODAF)

And finally, to build on the previously mentioned cooling types we land on Oil Directed/Air Forced (ODAF). This type Includes all the above-mentioned features of Oil Forced/Air Forced (OFAF) but additionally utilizes baffles within the transformer to direct the flow of the oil as it passes through the windings. This is often referred to as directed flow and indicates there is some form of control as to how the oil flows through the transformer tank, directing the oil the way in which it has the greatest impact in heat dissipation from the windings. Once again, furthering the transformers loading capabilities (see Figure 4).

Figure 4



It is important to note that most transformers will have multiple ratings that are a combination of different cooling types and operate in stages. Each stage of cooling that is implemented during operation allows for additional loading capacity above the previous stage.
For example, ONAN/ONAF/ONAF would be considered the most used liquid immersed power transformer design used in substation applications throughout the US. ONAN/ONAF/ONAF indicates three stages of cooling ratings are available. The first, as we learned above ONAN, being a natural convection of oil through external cooling, such as radiators. The second stage of cooling is the addition of a bank of cooling fans ONAF and the third being the addition of one more back of cooling fans. Each stage effectively has a rating at which the transformer is capable of being loaded to per the design requirements.

The cooling types previously listed are certainly not all inclusive, there are many other classifications, but this would be primarily what we see used most often today in the US market.

**Liquid immersed power transformer cooling systems are essential for ensuring the reliable and efficient operation of these critical components in electrical grids.
By effectively managing heat generation and dissipation, these systems play a vital role in preventing equipment failures, minimizing downtime, and maintaining power quality.**

Cooling Control

Traditionally we have measured transformer temperatures via mechanical gauges for values such as Liquid and Winding Hot-Spot Temperature then utilized these temperatures to appropriately regulate the cooling systems such as fans or pumps. Many advances have been made over the years to greatly improve the mechanisms in which we use today to make the decision of when to operate each stage of cooling.

Transformer cooling control systems, sometimes called ETMs, are designed to maintain optimal operating temperatures by precisely regulating the cooling mechanisms.

Cooling Control(Coolers)

Photo: Advanced Power Technologies

Strategically placed sensors monitor temperatures and other transformer parameters allowing the control system to determine the appropriate cooling response.

For example, if the winding hot spot temperature rises above a predetermined threshold, the system might call for a bank of fans or initiate oil circulation. Conversely, if the temperature drops below the desired range, cooling mechanisms may be reduced to conserve energy.
This dynamic control ensures that the transformer operates efficiently and safely, preventing overheating and extending its lifespan.

Conclusion

Liquid immersed power transformer cooling systems are essential for ensuring the reliable and efficient operation of these critical components in electrical grids.
By effectively managing heat generation and dissipation, these systems play a vital role in preventing equipment failures, minimizing downtime, and maintaining power quality. The selection of an appropriate cooling system depends on factors such as transformer size, loading conditions, and environmental considerations.

Recent innovations in cooling control systems have significantly improved the precision and efficiency of transformer temperature management. Advanced sensors, data analytics, and automation technologies enable more accurate monitoring and control of cooling mechanisms, leading to optimized performance and energy savings. These advancements are crucial for ensuring the long-term reliability and sustainability of power grids.

Advanced sensors, data analytics, and automation technologies enable more accurate monitoring and control of cooling mechanisms, leading to optimized performance and energy savings.

Oil Natural/Air Forced (ONAF)

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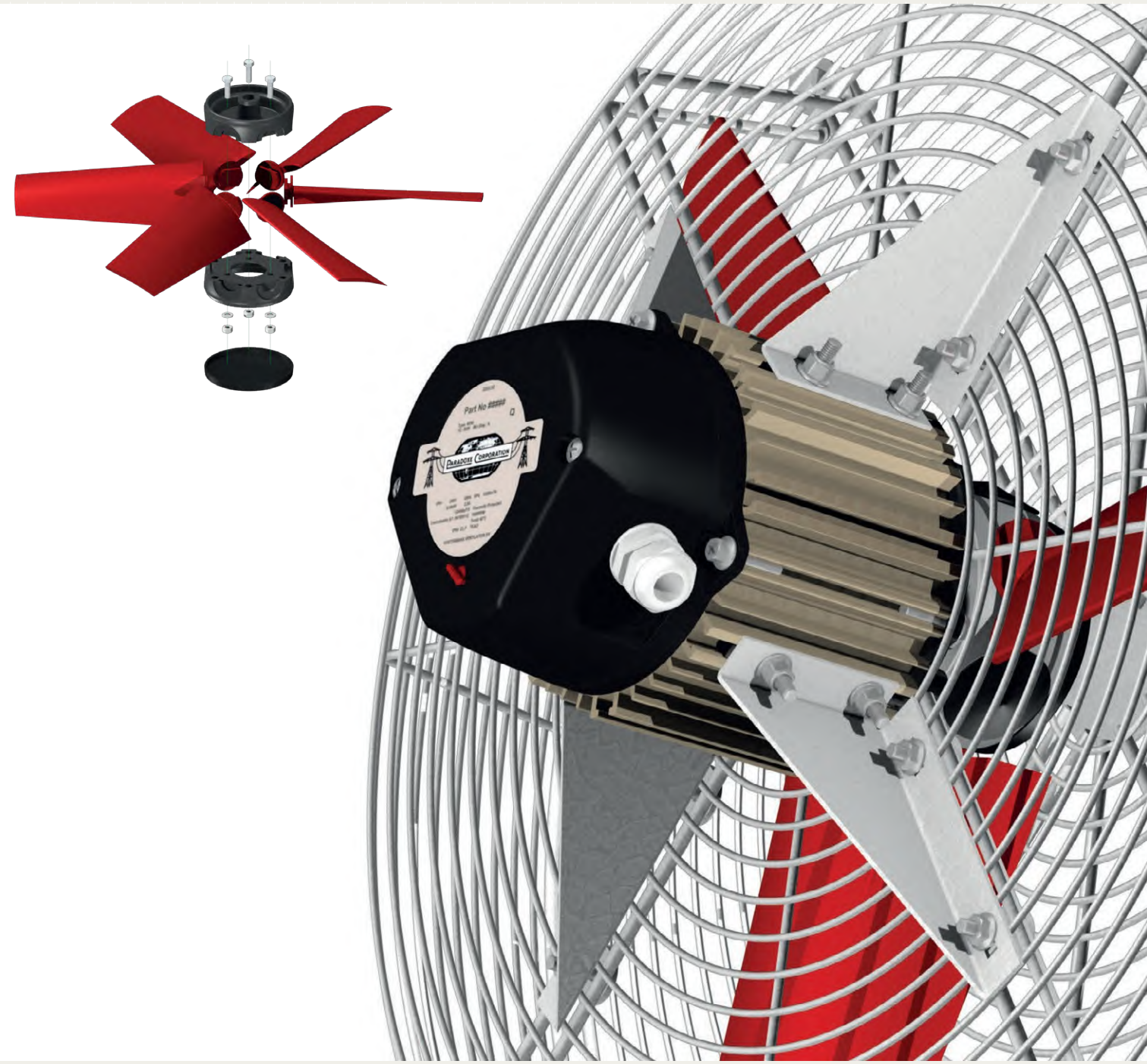
While it is common for portfolios to consist of a number of standard motors, we believe that customization makes the difference. For our fans, we have the flexibility to choose from hundreds of motors with different characteristics. This allows us to create the ideal motor and impeller combination. When we balance this combination, the efficiency of the fan improves and the motor load is reduced, which leads to extended service life. In addition, it ensures that most motors can withstand 10% overvoltage and 10% undervoltage. This prevents fan failures in areas where power grid fluctuations are common.



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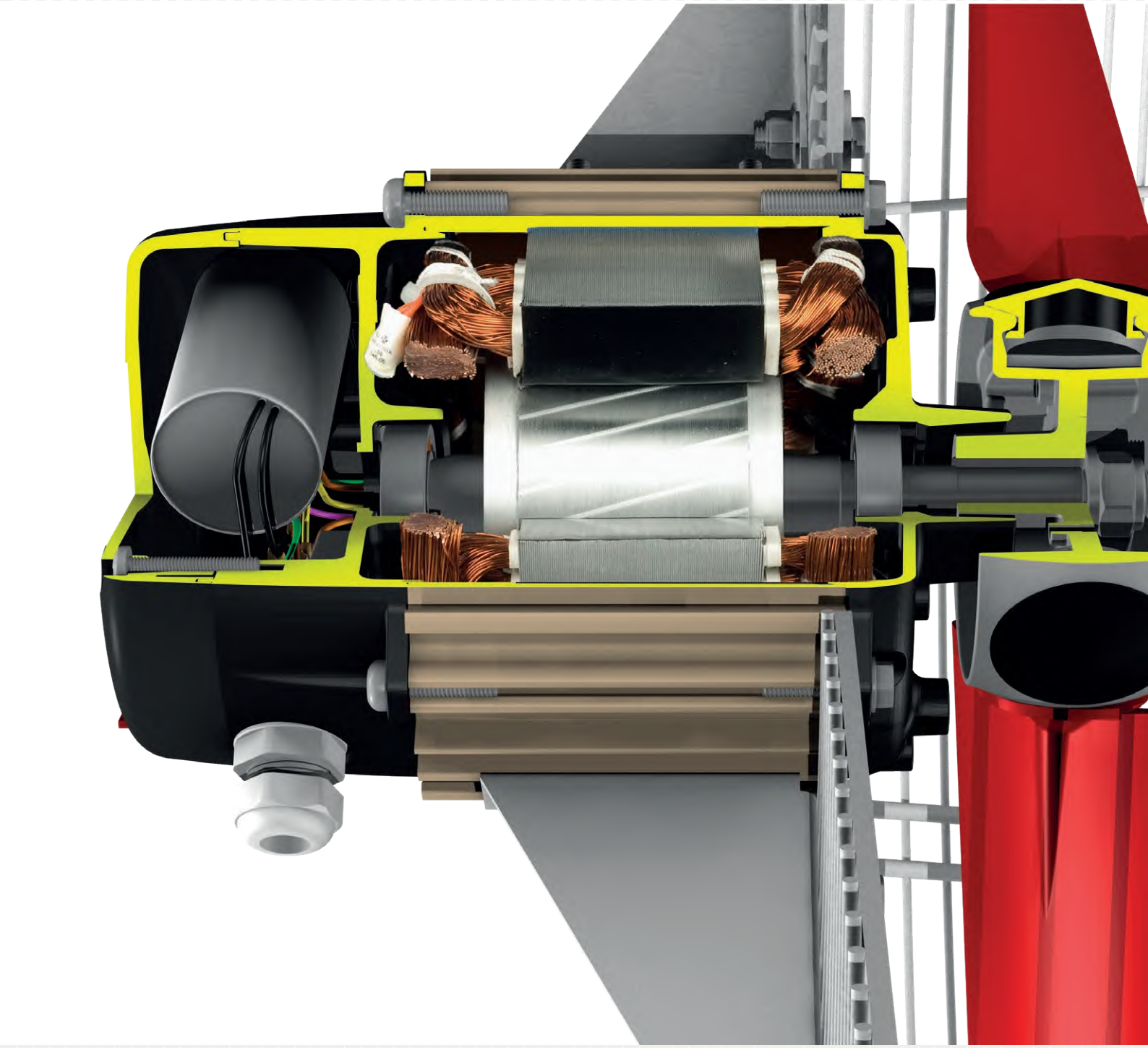
Our motors are IP55 Certified, which means that it is impossible for large amounts of water spray or dust to enter the motor. Condensation alone allows at least 0.5 liters of water to flow through the motor annually. Therefore, it is essential that moist air escapes the motor. Our motors have special drainage channels, which extend the service life of the motor.



Practical Application

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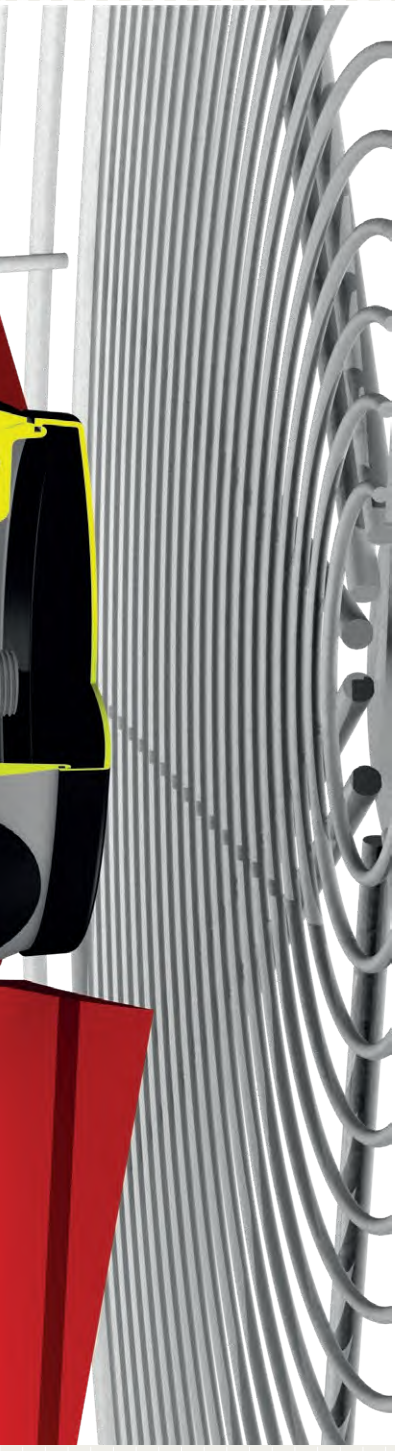

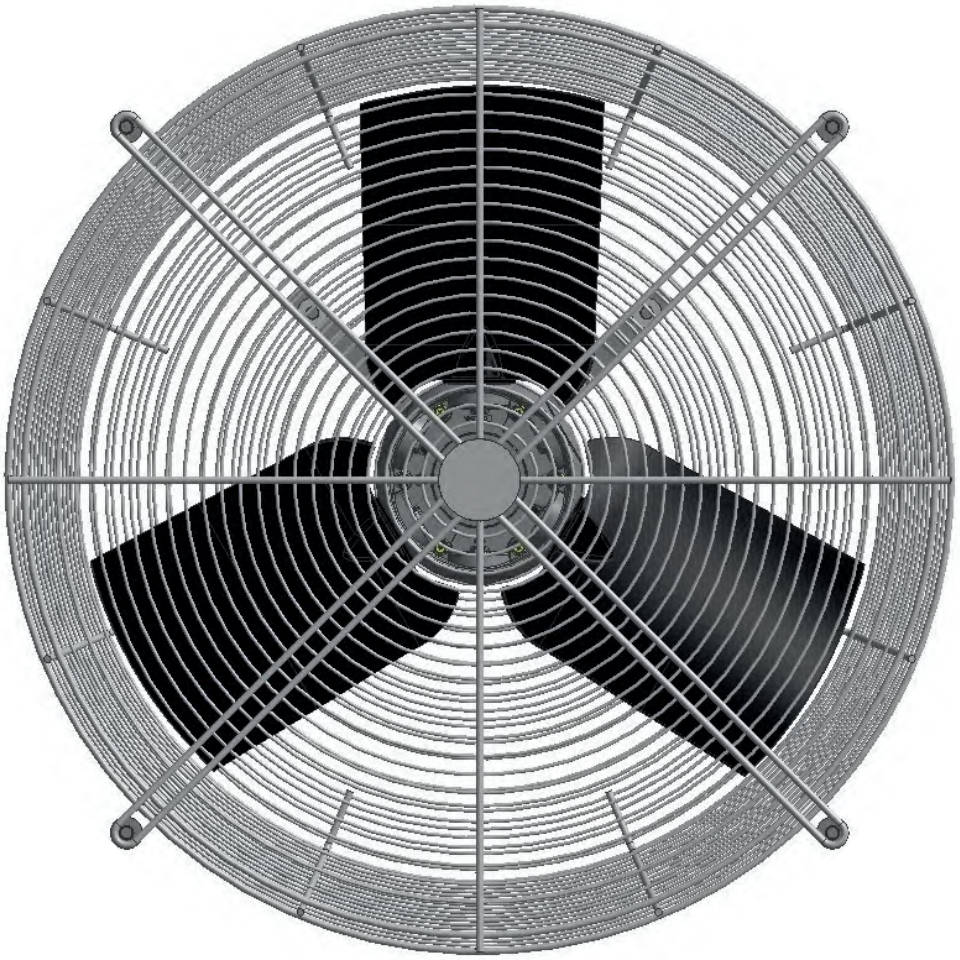

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Headwinds in the Space - How Can You Navigate the Market Slowdown?

Ever drove an electric car (EV)? They are fun to drive. The acceleration is unmatchable. The less fun part, however, is the charging of these electric vehicles. From finding a public charger to operating several apps to pay with the right one. Combine that with the lower availability of fast chargers (depending on the part of the world you are in), the overall EV charging experience becomes a complicated one. Things have improved significantly in the recent past though. There are a lot more fast DC chargers available today than two years ago.

If you are in the business of selling these chargers, or in the eMobility ecosystem in general, the last few years were a great time to be in this business. The demand grew in double digits in several countries across the world with the increasing adoption of EVs. Things, however, are different now. 2024 was the first year since the "EV boom" started where we see a down-turn in the market - which ranges from mild to quite significant, depending on the part of the world you are in. Both in Europe and the US, the EV chargers' market is facing a downturn, albeit for different reasons.

Reasons for a slowdown in the European and the US EVs and EV Chargers Market

In Europe, the slowdown in the eMobility market is caused by the elimination of subsidies for EVs, coupled with the economic situation. Germany, for example, eliminated environmental bonuses for EVs which has had a negative impact on the consumer sentiment. Leading to a 32% drop in sales between January-August 2024, compared to the same period last year in 2023. The CPOs in Europe are also facing financial challenges due to the low utilization rates. In addition to the lengthy and complex permitting process for grid connection, leading to additional organization and financial resources being spent. These changes are directly impacting the public chargers market. Several EV charger manufacturers are struggling to achieve profitability. Something we see impacting the broader ecosystem, with EV automakers and EV battery manufacturers struggling as well.

In the US, the situation is, however, slightly different. Despite the incentives in place for the last few years, the EV market has been growing at a slower pace than expected. Consumers have not been inclined towards EVs due to their higher cost and the low reliability of the current EV charging infrastructure (EVCI) in the US. Biden administration had been promoting EV adoption through tax incentives as part of the Inflation Reduction Act (IRA) and by funding public EV charging infrastructure

Photo: Shutterstock

2024 was the first year since the "EV boom" started where we see a down-turn in the market - which ranges from mild to quite significant, depending on the part of the world you are in. Both in Europe and the US, the EV chargers' market is facing a downturn, albeit for different reasons.

through National Electric Vehicle Infrastructure (NEVI) program. A total of USD 7.5 Billion was earmarked over 5 years to build a national network of 500,000 EV charging stations. However, due to the delays in the funding being administered, as well as the delays in permitting for the grid connections, only 192,000 charging points have been deployed. Like Europe, auto-makers and charger manufacturers are facing financial challenges in the US as well. In early 2024, US automakers successfully advocated for a change in government EV targets, from 50% annual share of car sales in 2050 to as low as 35% by 2032. This situation is expected to be further impacted by the change in administration after the recent elections, that could roll back much of the incentives in place and change the end of decade targets significantly.

> **In Europe, the slowdown in the eMobility market is caused by the elimination of subsidies for EVs, coupled with the economic situation. In the US... Consumers have not been inclined towards EVs due to their higher cost and the low reliability of the current EV charging infrastructure (EVCI) in the US.**

How will the European and US markets evolve in the current scenario?

Given all these changes, here is how PTR expects the market in Europe and the US to evolve until the end of this decade.

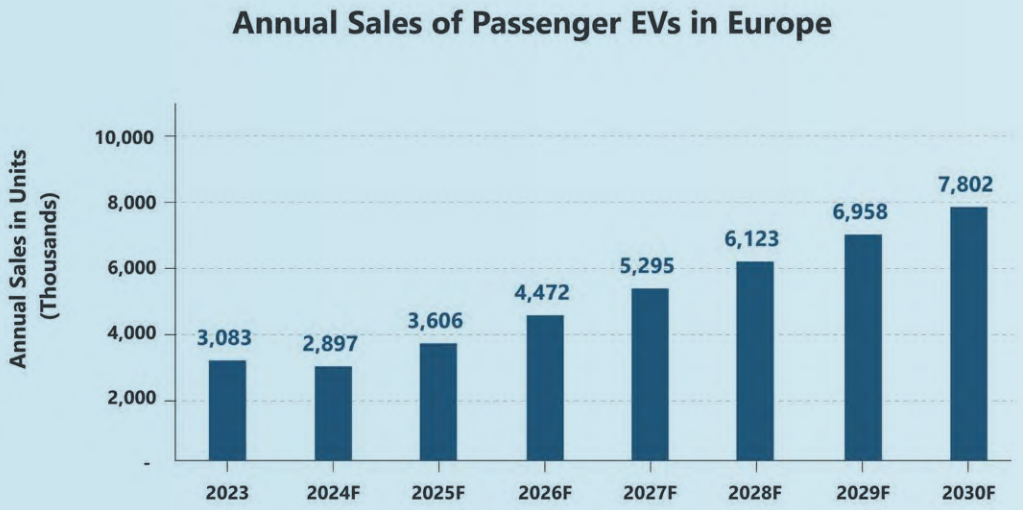

Figure 1: Annual Sales of Passenger EVs in Europe, Source: PTR Inc.

European EVs & EVCI Market

In Europe, 2024 is expected to close lower than the last year, with around 6-7% reduction in passenger EV sales and around 4% reduction (by revenue) in public chargers' sales. This change is coming at the back of some notable market drop-offs for BEVs* incl. Germany (-32%), Sweden (-21%) and Italy (-12%) but supported by strong market performers like Denmark (+50%), Belgium (41%), UK (+10%) and France (+11%).

Moving forward, PTR expects the EV market to recover and continue to grow, albeit at a lower growth rate than previously expected. Between 2024-2030, EV sales are expected to grow at around 18% annually. Especially as it is expected that some new EV incentives will be introduced soon.

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The private charging market, mainly consisting of AC and DC low power chargers, is expected to follow a similar trajectory as the EV sales, growing at around 20% (by revenue) annually until 2030. The public chargers market, however, which is dominated by DC chargers, is expected to grow at a much slower pace at around 7% annually until 2030.

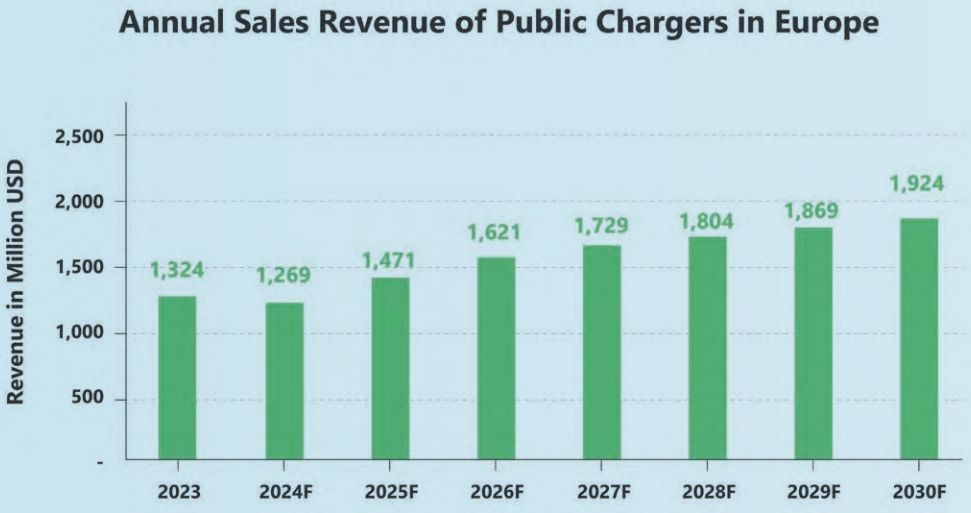

Figure 2: Annual Sales Revenue of Public Chargers in Europe, Source: PTR Inc.

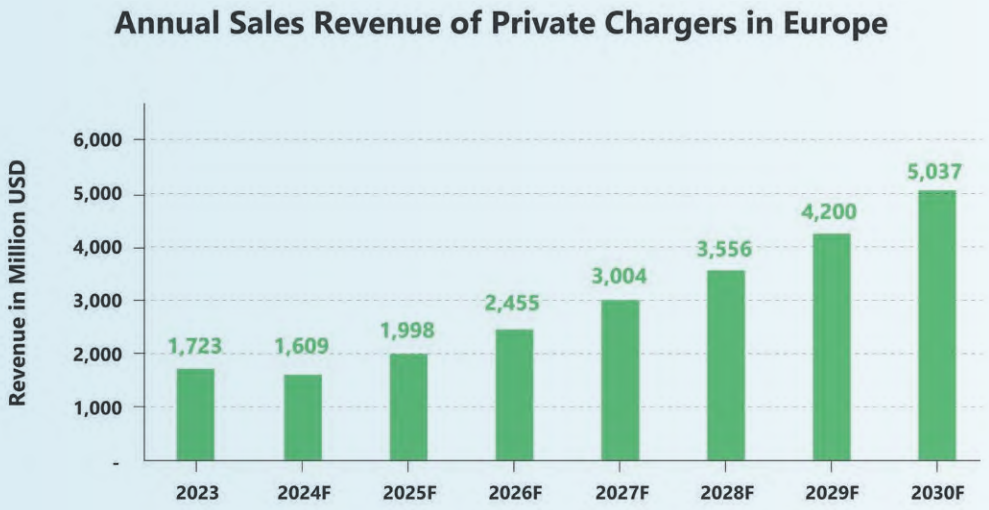

Figure 3: Annual Sales Revenue of Private Chargers in Europe Source: PTR Inc.

Despite the current situation, this growth is expected because the underlying drivers of the market are in place. These include regulations and funding sources like Alternative Fuels Infrastructure Regulation (AFIR/AFIF), as well as the EV adoption incentives and targets set by major European markets like UK's GBP 1.6 billion funding for EVCI until 2030 and France's 2030 investment plan of EUR 3.6 billion for EVCI.

US EVs & EVCI Market

The US EV market is slowly stagnating. In 2024, EVs held a share in annual car sales of around 10%, up from 4.3% in 2021, but far from the initial target of 50% annual EV sales by 2030. Contrary to Europe, however, PTR forecasts 2024 to end with slightly higher total EV sales than the last year by around 5%. Without taking into consideration any announcements by the upcoming administration, PTR was estimating the EV sales to continue growing at a stronger rate beyond 2024 at a CAGR of 20% between 2024-2030. Public EVCI was also expected to continue growing at a higher pace at around 18% annually between 2024-2030 due to projects in pipeline for which funding has been applied. This forecast, however, will be adjusted as the new administration takes office in January and issues new directives or regulations, potentially rolling back the incentives and targets.

At the time of writing, we expect the revised market growth to be as low as 10-15% in the coming years until 2030, expecting the rollback of incentives through the new announcements.

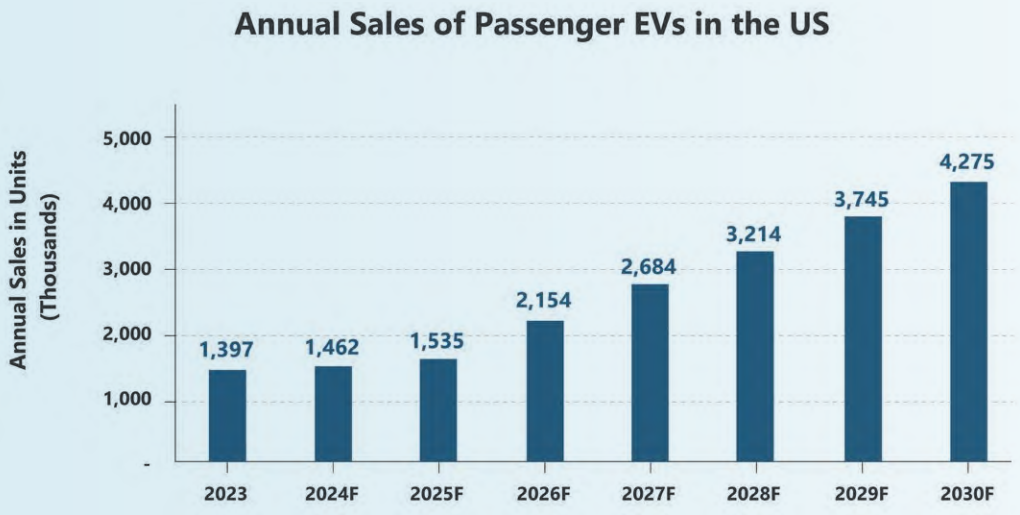

Figure 4: Annual Sales of Passenger EVs in the US Source: PTR Inc.

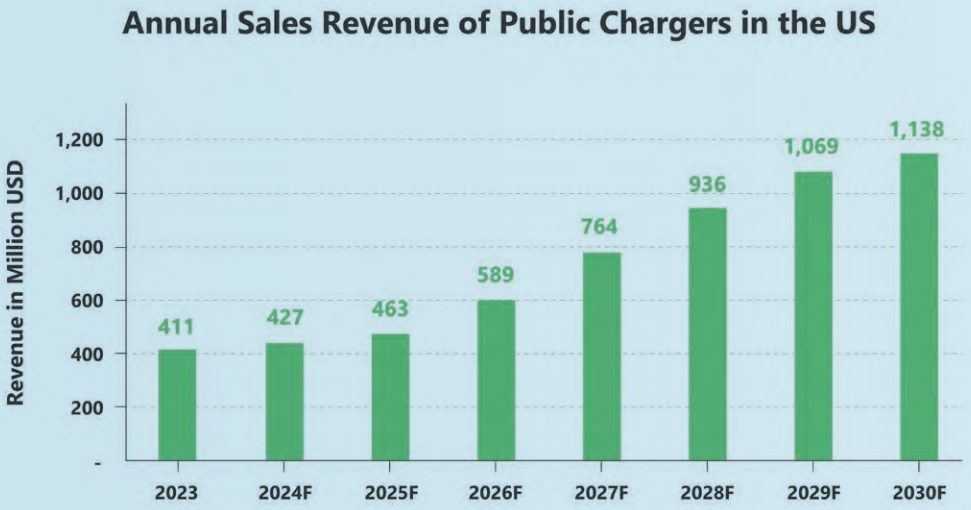

Figure 5: Annual Sales Revenue of Public Chargers in the US Source: PTR Inc.

However, we expect that the local manufacturing incentives for the automotive industry will continue, including EVCI. International manufacturers who have started manufacturing locally in the US (e.g. LG electronics, Alpitronic, Nidec, etc.) would benefit from the tariffs on imports, and the projects already put into motion (e.g. ChargePoint/Mercedes Benz/ Starbucks partnership, $500M investment in the Supercharger network etc.) will see their completion.

Embracing the headwinds - Positioning your company for success

Even though the market is still expected to grow, it is expected to grow significantly more slowly than previously thought, with a potential for stronger growth 2-3 years down the lane. With the market evolving in this way, if your company is in the eMobility business, you should set these two main priorities for your business as soon as possible: managing costs and cash flow in the short-term and investing strategically in product/service portfolio and market positioning to capitalize on the eventual recovery of the market. Easier said than done, but here are a few actions to consider:

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Customer Retention & Loyalty:

Offer enhanced support, maintenance packages and training to existing customers to strengthen relationships. Introduce flexible financing and leasing options to lower the investment barriers and risk.

Government & Regulatory Environment:

Work with policy makers and advocate to extend or create subsidies for EVs and EVCI. Propose regulatory frameworks that ensure long-term sustainable demand creating new opportunities in the economy.

Diversification, Diversification, Diversification:

Focus on countries where EV adoption remains strong, which could either be your existing markets or new markets for you to enter. Develop offering for specific customer segments like fleet operators and commercial buildings which might continue to grow despite the overall slowdown.

Photo: Shutterstock

Try to grow revenue through adjacent services like service contracts, warranty extensions and flexible installation contracts in phases.

Scenario Planning & Agility:

Continuously monitor market trends, regulatory shifts and competitive dynamics to be ready to respond as quickly as possible. Lessons from Covid - companies that adapted quickly to the changing situation, came out on the other side much better than the others.

If you can survive in the market today, there is light at the end of this short tunnel. If you can respond to the changing market situation by acting quickly, in the medium-term, you will be ready to gain from the market recovery.

With the eMobility market changing so rapidly, PTR is actively tracking the new announcements and updating our forecasts accordingly and will share more strategic insights as we update our forecasts over the coming weeks.

About PTR:

With over a decade of experience in the Power Grid and New Energy sectors, PTR Inc. has evolved from a core market research firm into a comprehensive Strategic Growth Partner, empowering clients' transitions and growth in the energy landscape and E-mobility, particularly within the electrical infrastructure manufacturing space.

Author:
Hassan Zaheer
Chief Operating Officer
PTR Inc.

Hassan Zaheer is the Chief Operating Officer at PTR Inc. based in Abu Dhabi, UAE. With more than a decade of experience in the energy transition space, Hassan works for various Fortune-500 blue-chip clients on global market studies in the electrical infrastructure sector. In his current role at PTR, he works with clients to sustainably grow their businesses, both through custom consulting work and tailored research reports by PTR, helping their executive management and boards make data driven decisions. Hassan is also a Member of Advisory Board for CWIEME Berlin and an advisor to the educational non-profit Better Humans Academy. Hassan has a tech background with a Masters in Power Engineering from the Technical University of Munich (TUM) and a BS in Electrical Engineering from the Lahore University of Management Sciences (LUMS). Additionally, he is also an Alumni of Center for Digital Technology & Management (CDTM).

COMPANY SPOTLIGHT
BEST TRANSFORMER

BEST Transformer's factories located in Balikesir, Türkiye

“ Türkiye's Pioneer and Leader in Global Transformer Market

Company can produce transformers 50.000MVA/year

As Türkiye's first high-voltage transformer manufacturer, **BEST Transformer** was founded in 1966. Since then, the company has made its mark in the industry with a production area of 170.000 m² and an annual production capacity of 50.000 MVA. Today, BEST Transformer has become a global company, exporting over 80% of its products to more than 110 countries.

BEST Transformer is not only a manufacturer, but also an innovator in the electromechanical sector, leading many advancements with its R&D and technological investments over 5% of yearly turnover, which is more than double of EU or Türkiye average R&D spending by GDPR. With over 300 engineers and over 1,500 employees, the company is focused on creating a sustainable ecosystem. BEST Transformer also contributes to environmental and social benefits, signing the United Nations Global Compact in 2019, bringing its socially conscious vision to global standards and offering trademark sustainable solutions as BEST Friend.

With international quality standards such as TS, ISO, IEC, ANSI, GOST, and BS, BEST Transformer stands out as a technology provider in the sector. Its product range is extensive and versatile: up to 1250 MVA 765 kV Power Transformers, from 50kVA up to 16 MVA 72.5 kV Oil Distribution Transformers, up to 40 MVA 72.5 kV Dry-Type Transformers, and various custom transformer solutions for every need.

BEST Transformer continues to push the boundaries in the industry worldwide. The company broke a world record with a 310 MVA furnace transformer it produced in 2014 and renewed this record in with its 315 MVA transformer developed using Booster technology. 130kA current flows through windings of this marvel.

In 2018, BEST Transformer produced a 450 MVA auto-transformer, which

Company record is 3 phase 650MVA autotransformer, can manufacture up to 1250MVA

successfully passed the short-circuit test, setting a new world record. Additionally, the company's 180 MVAr 525 kV Magnetically Controlled Shunt Reactor also holds another world record. BEST set a milestone by manufacturing Turkey's largest dry-type transformer, with a capacity of 34 MVA and a weight of 63 tons. BEST Transformer is also a trusted partner for renewable energy companies in countries such as USA, France, Belgium, Germany, Spain, and the United Kingdom.

BEST Transformer has achieved two significant projects this year. 650 MVA 400/170/36 kV transformer set a new factory record, marking its place in BEST Transformer's history as the largest three-phase autotransformer produced. With 3 x 533 MVA 525 kV total of 1600MVA high-power transformers, BEST is achieving success in the USA as well. The company also exports many power transformers and reactors to the continent.

BEST Transformer continues to create a sustainable impact on a global scale, prioritizing environmental and social responsibility at every opportunity, and maintains its leadership in the sector through its production technologies and high-quality standards.

Learn More:
https://www.besttransformer.com/en/

Contact:
best@besttransformer.com

Linkedin:
https://www.linkedin.com/company/besttransformer/

Photo: BEST Transformers

Surging Demand: Resilient Coatings for Our Most Important Infrastructure

by **Maria Lamorey**

A KEY PART IN REFURBISHING AGING TRANSFORMERS AND POWER SUPPLY EQUIPMENT IS UPDATING THE EXTERIOR PROTECTION, INCLUDING SANDING, PRIMING AND PAINTING WITH A DURABLE INDUSTRIAL COATING ENGINEERED TO DEFEND AGAINST CORROSION. THIS IS IMPORTANT BECAUSE OUTDATED COATINGS SYSTEMS ARE TYPICALLY NOT AS DURABLE, PARTICULARLY AFTER DECADES OF HARSH WEATHER EXPOSURE.

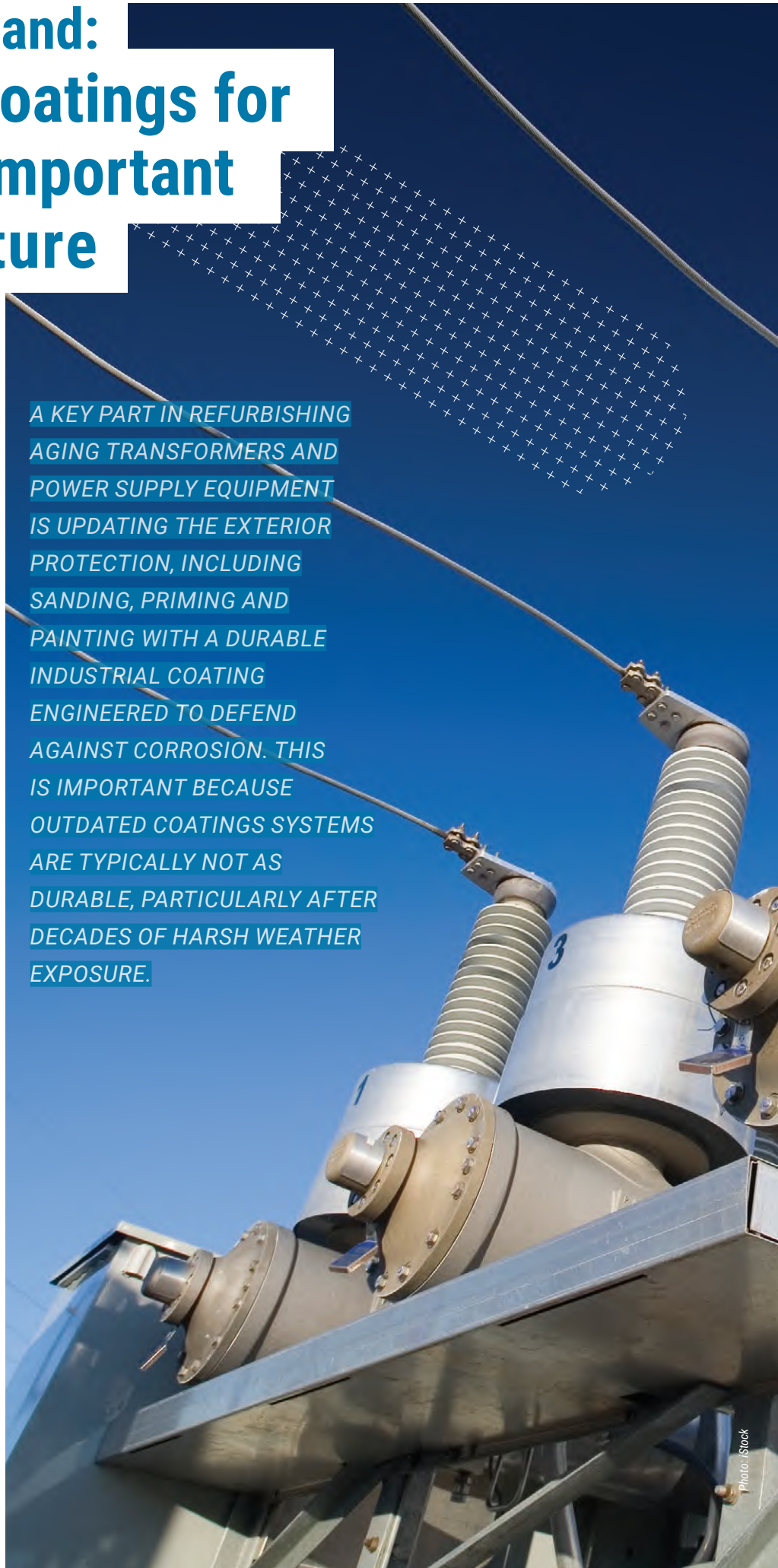


Photo: iStock

Advanced Coatings Help Curb Transformer Supply Challenges: Enhancing Durability, Performance in a Strained Energy Sector

There are a host of factors driving the ongoing shortage of transformers, including manufacturing growth, intense heatwaves, electrification and widespread adoption of renewable energy sources, all requiring an expansion of the energy grid to support new equipment and transformers. However, demand will only accelerate with the boom in Artificial Intelligence (AI) and the power needed to operate a growing number of AI data centers.

According to a report by the International Energy Agency, global electricity demand is expected to rise at a faster rate over the next three years, growing by an average of 3.4% annually through 2026, driven in part to data center energy needs.

Transformer manufacturers have found it challenging to scale up production to meet the demand, putting an immense strain on the supply chain. Long-wait times are now the norm with no signs of easing. In fact, lead times are currently sitting at between 115 to 130 weeks on average.

The limited inventory of parts and aging infrastructure pose risks to critical systems that power vital networks, such as hospitals, communication networks, water and waste management, and even military bases.

The U.S. Department of Commerce reports that the average age of

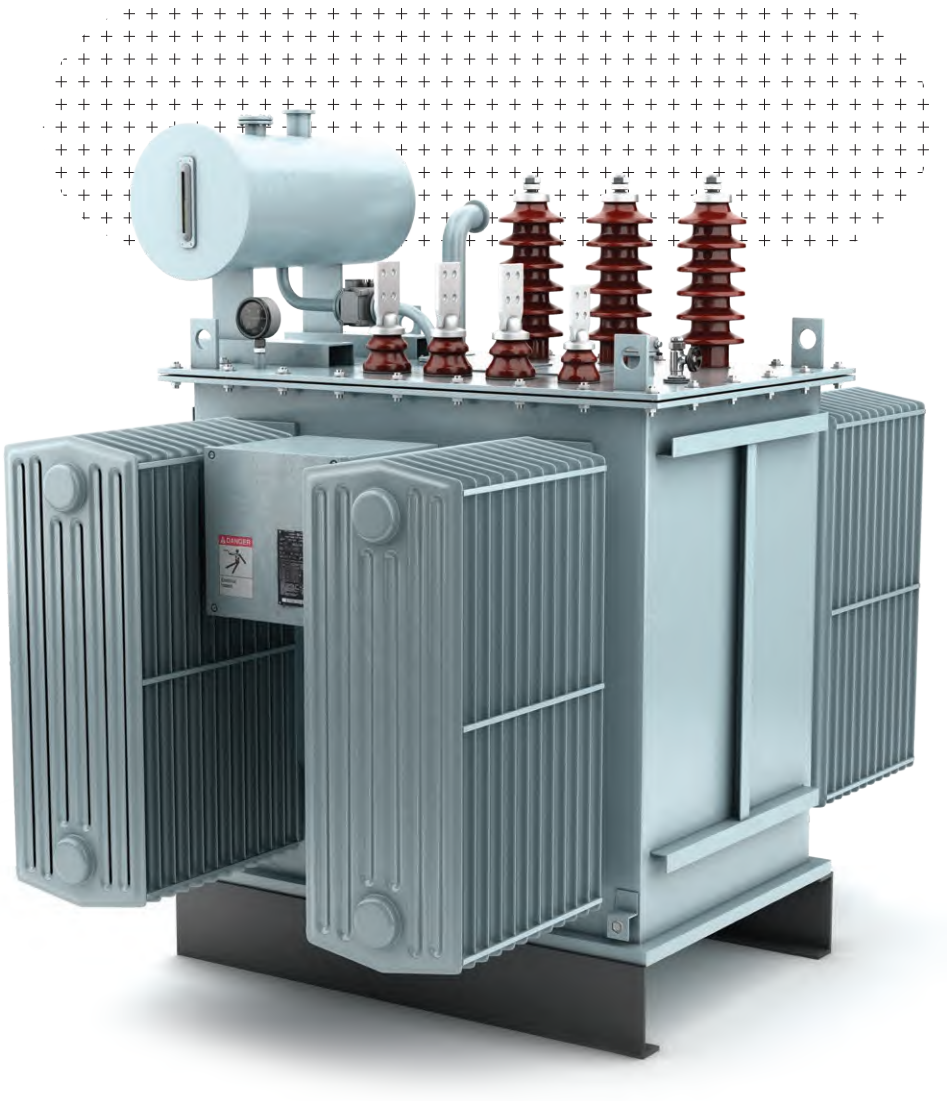
Maria Lamorey is the Commercial Strategy Manager – Americas for PPG. With more than 20 years of industry experience, Maria plays a leading role in PPG's commitment to delivering high-performance coatings products across a variety of general industrial applications including all types of electrical equipment. Maria is a certified instructor for a nationally PDH accredited course on material science in electrical equipment design and has been an active member of the IEEE Transformer Committee and NEMA (National Electrical Manufacturers Association).

transformers in use is 38 years—approaching the end of their expected lifespan—with 70% of them being older than 25 years.

In light of the scarcity of new equipment, refurbishing and maintaining existing transformers is becoming particularly crucial. Restoring and updating these components, including their exterior protection with high-quality industrial coatings, can help curb supply challenges and help address growing demand.

Although it might seem inconvenient to update coatings systems that have not yet failed, now is an ideal time for manufacturers to reassess their protective technologies and consider newer, more effective solutions before a more widespread problem presents itself.

A key part in refurbishing aging transformers and power supply equipment is updating the exterior protection, including sanding, priming and painting with a durable industrial coating engineered to defend against corrosion. This is important because outdated coatings systems are typically not as durable, particularly after decades of harsh weather exposure. This vulnerability can lead to significant power service disruptions and equipment failures, which can be life threatening, particularly in the current climate with rising temperatures worldwide.



Future-Proofing with High Corrosion Protection

When it comes to the metal components on a transformer, corrosion is public enemy number one.

Metal electrical equipment parts corrode for any number of reasons. Some factors include the intersection of two metals with different corrosion thresholds, or continuous or repeated exposure to high temperatures and humidity from decades in the field, damaging pH (acid) levels, electrolytes, chemicals and ultraviolet rays from sunlight.

Selecting the proper coating materials to help preserve power generators, transformers, switchgear and more is the first line of defense. The right coating system that offers durability and resilience at every layer of protection—from pretreatment through finish coat—can extend the service life of the part and reduce the risk of coatings-related equipment failures.

First Up: Review Your Current Paint Specifications

While most electrical equipment has a minimum life expectancy of 20 years, many components are expected to survive 50 years or more. Harsh elements can accelerate corrosion and leave sensitive instrumentation vulnerable and potentially unreliable.

Unfortunately, many manufacturers still combine old "cut-and-paste" specifications that date back 20 to 30 years with current industry-standard regulatory requirements written by IEEE, UL, CSA and ASTM when painting and protecting new equipment.

On average, finished electrical components are composed of about 70% metal and 30% non-metal substrates, yet nearly 100% of electrical equipment manufacturers view painting metal as beyond their core competency. An average-sized switchgear manufacturer running 10 to 15 million square feet of coated metal through its facility is staking a lot of its reputation on work considered outside of their scope.

If the goal of an electrical equipment manufacturer is to build next-generation components that exceed performance mandates while protecting its brand reputation, paint specifications should be reviewed and updated regularly. Innovations in industrial coatings have brought high-performance paint options to market that can significantly extend the lifespan of power equipment.

In addition to product scope and substrate type, manufacturers should consider the following when developing their specifications:

Coating Type
Coating manufacturers offer a variety of resin chemistries to improve resistance to corrosion and UV exposure, including epoxies, polyesters, urethanes and acrylics, as well as hybrid coatings, which incorporate a combination of resin chemistries. Each have their strengths and weaknesses.

For instance, epoxies are ideal for chemical resistance and mechanical properties, but are lacking in UV resistance and weatherability.

Polyesters, urethanes and acrylics all offer exceptional weathering

Photo: iStock

THE RIGHT COATING SYSTEM THAT OFFERS DURABILITY AND RESILIENCE AT EVERY LAYER OF PROTECTION—FROM PRETREATMENT THROUGH FINISH COAT—CAN EXTEND THE SERVICE LIFE OF THE PART AND REDUCE THE RISK OF COATINGS-RELATED EQUIPMENT FAILURES.

characteristics, but each offers a different benefit, such as great physical properties for polyesters; chip, scuff and mar resistance for urethanes; and exceptional surface appearance for acrylics.

Product Codes
Electrical equipment producers should avoid using a specific paint manufacturer's product code. Codes can be ambiguous or difficult to find, as they often change or may be unique to a specific customer. Instead, detail the specific coatings technology the equipment demands (pretreatment, liquid, powder or electrocoat); then detail the resin chemistry of the desired coating.

Color
Establishing and maintaining a standard color can be challenging. It is important to detail an acceptable range of color variation and use a proven and consistent method for determining that the color of a painted parts falls within specification.

- Pantone, RAL, Munsell, and ANSI are color-cataloging systems commonly used for these purposes, although some equipment manufacturers choose to create their own in-house standards. Maintaining color standards is a whole separate topic, so it is best to work with a reputable paint manufacturer to understand the intricacies of creating a color standard and how to detail its parameters in the specification.

Gloss
Like color, the gloss range specification can have a big impact on a product's finished appearance. It is important to provide a specific gloss range in a paint specification, as variations in gloss can cause the same color on a piece of equipment to appear as different shades.

Texture
In the electrical industry, some orange peel (minor paint dimpling) in the finish is considered preferable, as it tends to hide flaws and wear well over time. Regardless, standards for texture types and variation should be written into the paint specification.

Product Handling and Storage
Manufacturers suggest specific rules for handling and storage in their product data sheets, including an acceptable range of temperature exposures and fixed expiration dates to ensure inventory is properly rotated.

Performance
Regulatory standards such as UL or IEEE should be detailed in the paint specification. These standards are written to include a range of acceptable results for products undergoing laboratory-based performance tests, which have been agreed upon by the industry for their ability to mimic real-world performance environments.

Ensuring Long-Term Durability: Performance Testing for Coating Systems

While many coatings systems are sufficiently robust to pass industry-accepted performance tests, they can fail in the field because the real-world conditions are often more challenging.

For that reason, it is critical to include the tests that most accurately reflect a product's ability to fulfill a warranty or an expected service life in the paint specification. For example, does a specific impact test predict paint chipping once installed in the field? Or does an accelerated weathering test depict the real-world color fade or breakdown of a coating?

Performance testing must also correspond to field troubleshooting. If a coating fails in the field, correlating the failure to a specific testing method will enable the equipment and paint manufacturers to identify the reason for the failure, which can lead to quicker corrective actions.

Some of the most common performance tests written into an electrical equipment paint specification are detailed below:

Salt Spray
This is the most commonly specified test in the electrical industry. UL1332 requires 600 hours of salt-spray exposure for electrical enclosures and switchgear. Many transformers require between 1,000 and 2,000 hours of exposure.

Ultraviolet Accelerated Weather Testing (QUV)
In this test, coated panels are exposed to ultraviolet (UV) light of varying types, resulting in "maintain X% specific gloss level after X number of hours" rules as detailed in a specification. These tests are designed to predict how a coating will fade outdoors over time.

Simulated Corrosive Atmospheric Breakdown (SCAB)
In this test protocol, painted panels are scribed, then cycled through exposure conditions produced in the following environments: an oven, a freezer, immersion in an NaCl solution, room temperature, high humidity. The IEEE test for SCAB required 15 total cycles with prescribed times in each area. This testing is designed to predict how well a coating will maintain its integrity when subjected to a succession of regular and extreme performance environments.

Humidity Testing
During this test, painted panels are typically placed in a chamber for 1,000 hours, then examined for evidence of blistering or softening. This testing is designed to predict how well a coating resists water.

Impact Resistance
For this test, panels are exposed to an array of impact hazards, measured according to pounds. Transformers are typically tested at 80 pounds of impact. This testing is designed to predict how well a coating will resist force from an object, such as a tool or machine. It also may predict a coating's resistance to chipping when a bolt or other fastener is tightened onto its surface.

Cross Hatch Adhesion
In this test, a tool is used to cut a lattice pattern into a metal substrate. A quick pass/fail rating is assessed to the full coating system to gauge its ability to adhere to a substrate.

Gravelometer
Road gravel is air-blasted into coated panels, which are then placed into a salt-spray chamber to assess the corrosion resistance of the exposed parts. This test is designed to predict a coating's chip resistance and ability to withstand road gravel.

Photo: iStock

Other tests that are occasionally used and built into specifications for electrical equipment include:

Pencil hardness
During this test, a pencil is pressed through the surface of a coating to measure its adhesive strength.

Adhesion testing
This test method involves applying tape across a painted surface in a cross-cut method, then removing it to determine how effectively the paint sticks to the surface.

There also are many types of chemical tests, including an insulating fluids test to determine a coating system's ability to resist exposure to certain types of chemicals.

Optimized Power Equipment Coatings: Balancing Durability and Sustainability

Is your current coating technology utilizing the latest coatings advancements and the most sustainable options?

Liquid coatings use solvents or water and are applied to pretreated metal with electrostatic spray, dipping and other conventional methods before being air-dried or force-cured.

When used as part of an integrated primer, pretreatment and topcoat system, liquid coatings offer exceptional resistance to corrosion and chemicals, excellent sag resistance and strong adhesion. The newer product offerings in waterborne liquid technologies can offer a more sustainable option as part of an integrated coating layer.

Powder coatings are formulated for applications that require the ultimate combination of corrosion resistance, weathering performance and operational attributes. These coatings are typically formulated with specific resins combined to provide excellent corrosion and chemical resistance, as well as all-around application versatility.

Since powder coatings are made without solvents, they generate virtually no volatile organic compound (VOC) emissions, which can help to achieve environmental compliance and reduce material usage, energy consumption and maintenance costs thanks to a first-pass transfer rate of up to 85%.

Breakthrough Zinc-Rich Powder Primers Raise Corrosion Protection

Due to their advantages in sustainability, edge coverage and durability, powder technologies are growing in global prominence, including zinc-rich powder primers. While zinc is renowned for its corrosive fighting properties, its density poses challenges during application.

Recently, scientists achieved a breakthrough by formulating a zinc-rich primer with optimized zinc content. This patent-pending innovation boasts higher transfer efficiency, thanks to its lower specific gravity compared to standard zinc-rich primers (2.0 vs. 3.6). The reduced density makes it easier to apply, achieving an impressive 85% transfer efficiency. Although it contains less zinc by volume than traditional zinc-rich primers, it meets rigorous ISO C5 corrosivity standards, making it suitable for high-humidity and aggressive environments.

This well-balanced primer offers exceptional edge, face, and scribe corrosion resistance, semi-conductivity, and excellent adhesion on both smooth and blasted steel. Its robust bond withstands peeling, chipping, and degradation. In lab testing, the primer even surpassed 10,000 hours of salt spray performance on blasted steel.

Key Takeaways

When creating a paint specification, it is critical to correlate a component's expected operating environment and service life to the testing methodology that most rigorously replicates the performance challenges it will face. Not only will this help to ensure that a product performs reliably throughout its lifetime; it may also lessen overall maintenance requirements.

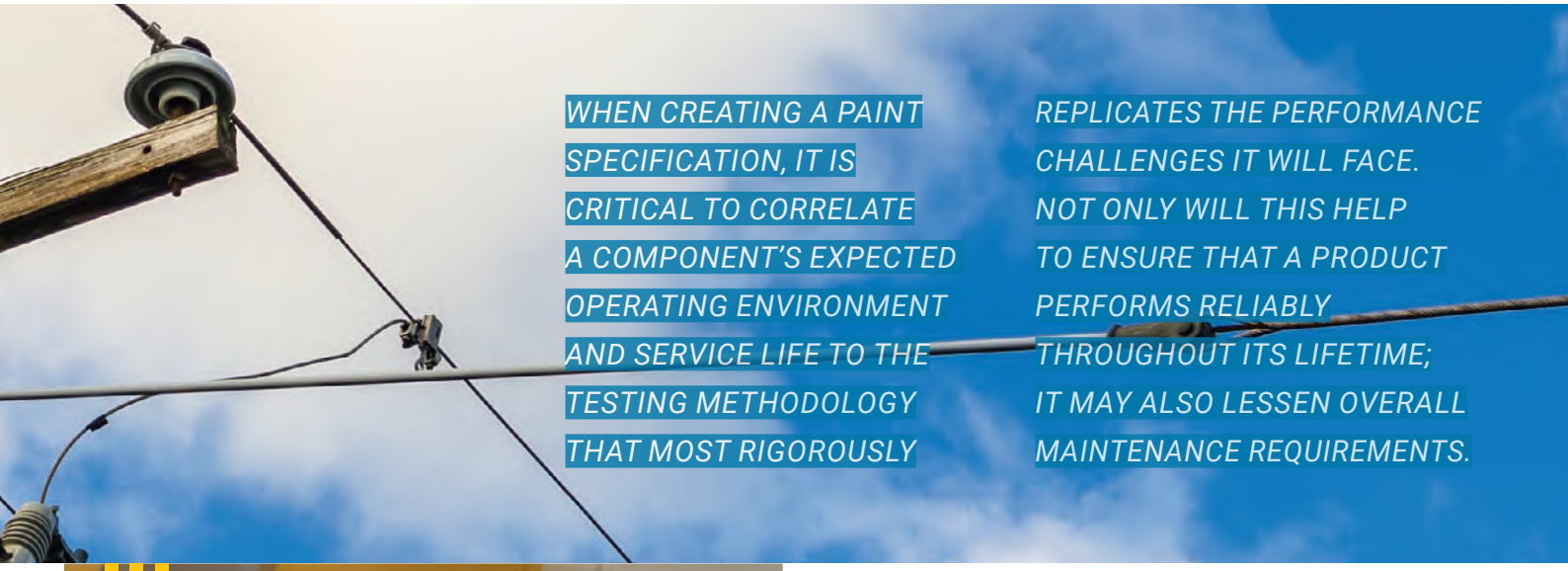
Equipment manufacturers should evaluate their paint specifications on a regular schedule to ensure that they always incorporate the most targeted and technologically advanced coating systems and testing methodologies for their specific application.

Photo: Getty Images

They may also want to consider partnering with paint and pretreatment suppliers in the design process as early as possible, preferably with a proven coatings company that can offer both pretreatment and paint capabilities as an integrated package.

Integrated, full-service coatings suppliers typically have a deep understanding of the coatings process from start to finish, along with a wide range of products and resin chemistries that have been tested according to industry-standard criteria.

These coatings suppliers can act as a partner in identifying potential vulnerabilities to corrosion and help customers to select the best products to prevent it. Most integrated coatings suppliers also have dedicated lab resources, which enables them to recommend the best test methodologies to measure a product's potential service life and troubleshoot general coatings-related production problems.



WHEN CREATING A PAINT SPECIFICATION, IT IS CRITICAL TO CORRELATE A COMPONENT'S EXPECTED OPERATING ENVIRONMENT AND SERVICE LIFE TO THE TESTING METHODOLOGY THAT MOST RIGOROUSLY REPLICATES THE PERFORMANCE CHALLENGES IT WILL FACE. NOT ONLY WILL THIS HELP TO ENSURE THAT A PRODUCT PERFORMS RELIABLY THROUGHOUT ITS LIFETIME; IT MAY ALSO LESSEN OVERALL MAINTENANCE REQUIREMENTS.

JOB POSTING

REPRESENTATION IN THE NORTH AMERICAN MARKET

For TTP and MPP Technologies

We are looking for an experienced representative to join us full-time and manage our sales and marketing activities in the North American Market on an exclusive basis.

The successful representative will oversee our sales and marketing activities in the North American market. You will be our representative and help us to hear our customers voice while working within a dynamic global team with a focus on North America.

RESPONSIBILITIES

- Promoting our services on the allocated market.
- Contacting potential customers in order to increase business growth.
- Communicating and exchanging information with the team.

REQUIRED SKILLS AND EXPERIENCE

The ideal Representative for this role should have:

- Experience in representing local markets.
- Solid network of professionals in the transformer and power industry.
- Related professional qualifications.
- Self-motivation and be goal-oriented.
- Strong teamwork skills.
- A good command of English in speaking and writing.

ABOUT THE COMPANY

TTP Technologies and MPP Technologies are manufacturers of transformer radiators and tanks which conform to German, European, American, and Japanese standards with a substantial presence in North America.

For more information about the company, visit: https://ttpradiators.com/

Contact email: sameer@ttpradiators.com and mdshetty@ttpradiators.com

TTP Technologies

MPP Technologies

Expanding Electrical System Safety with IRISS Safe Connect: Simplicity and Enhanced Operator-Driven Models

In the contemporary industrial landscape, the quest for enhanced safety, reliability, and efficiency in electrical system management has led to the adoption of cutting-edge technologies. Among these innovations, the IRISS Safe Connect range of thermochromic products has emerged as a pivotal tool, aligning perfectly with the rigorous guidelines outlined by the National Fire Protection Association's NFPA 70B for the maintenance and inspection of electrical equipment. This article delves into the transformative impact of the Safe Connect range, emphasizing its role in facilitating continuous monitoring, promoting ease of use, and augmenting operator-driven safety and reliability inspection models.

Revolutionizing Electrical System Inspections with Thermochromic Technology

The traditional approach to electrical system maintenance, heavily reliant on periodic infrared (IR) inspections, has long been a standard practice. While invaluable, this method presents inherent limitations, notably its snapshot-in-time nature and the operational constraints imposed by equipment design, significantly reducing the opportunity for continuous oversight. Recognizing these challenges, the IRISS Safe Connect range introduces a dynamic solution through its innovative thermochromic technology, offering a 365/24/7 over-temperature monitoring system. This continuous monitoring capability starkly contrasts with the episodic nature of IR inspections, which, even when conducted semi-annually, barely scratches the surface of the equipment's operational timeline, covering a mere 0.0038% of its running time.

The IRISS Safe Connect range introduces a dynamic solution through its innovative thermochromic technology, offering a 365/24/7 over-temperature monitoring system.

Unmatched Security and Operational Efficiency

The security and efficiency of electrical systems are paramount in industrial operations, where the cost of downtime or equipment failure can be astronomical. While effective to a degree, traditional IR inspections that do not utilize infrared inspection windows are hampered by accessibility issues and the need for operational pauses to carry out inspections. The Safe Connect range's thermochromic products transcend these limitations, providing real-time over-temperature visual alerts without direct interaction or operational interruption. This feature enhances the safety and reliability of electrical systems by allowing for immediate identification and remediation of potential issues and significantly reduces maintenance costs and operational disruptions.

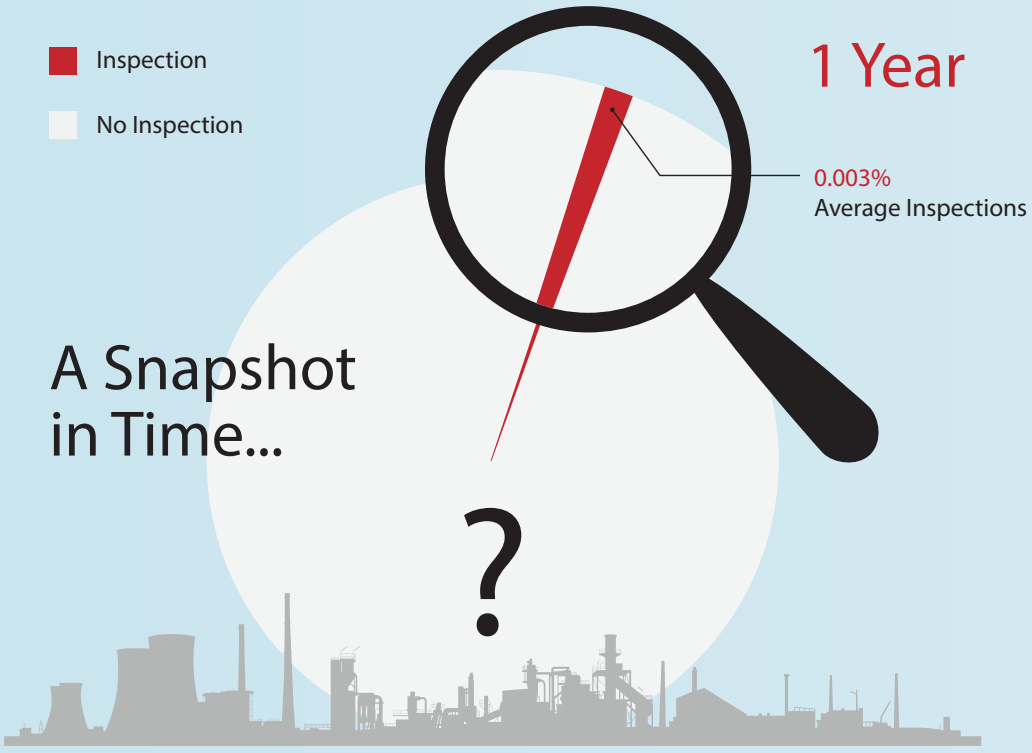
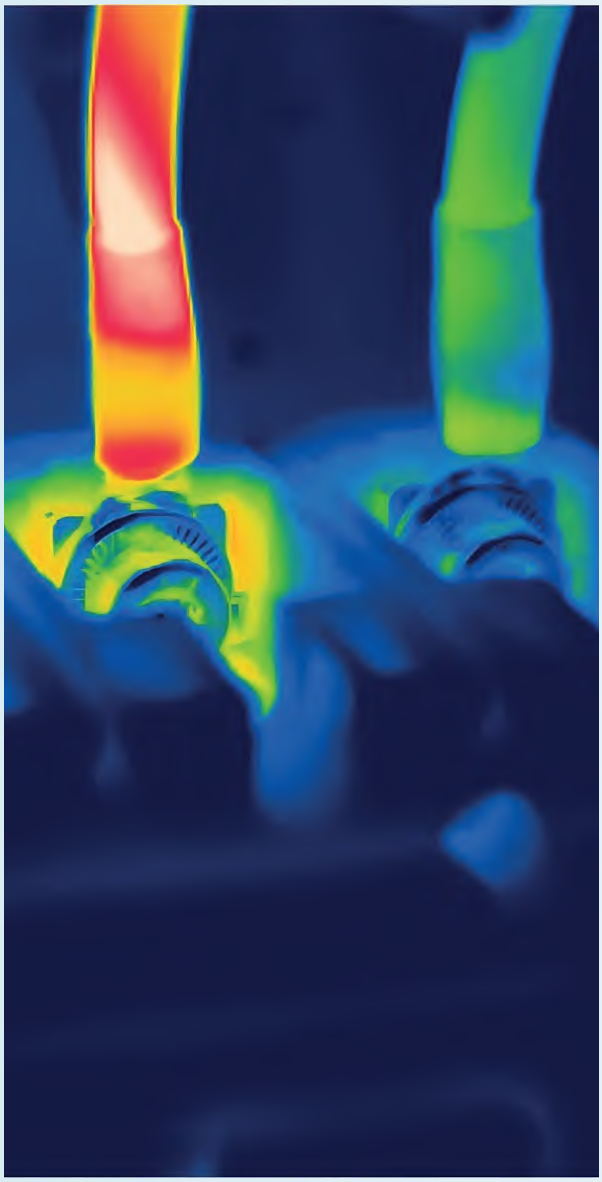


Photo: Shutterstock, IRISS Inc.



Simplifying Maintenance with User-Friendly Solutions

A cornerstone of the Safe Connect range's appeal is its inherent simplicity and ease of use. These thermochromic products are designed to be intuitive and do not require extensive training or technical expertise to operate effectively. This accessibility simplifies the process of electrical system monitoring, enabling a broader spectrum of the workforce to partake in maintenance activities. The visual feedback mechanism, where products change color in response to temperature variations, offers an immediate and easily interpretable indication of system health. This straightforward approach expedites the detection process and empowers staff to proactively address issues, thereby enhancing operations' overall safety and efficiency.

Catalyzing Operator-Driven Inspection Models

The integration of Safe Connect products significantly strengthens operator-driven safety and reliability models. In such models, operational personnel are encouraged to participate in the monitoring and upkeep of equipment actively. The simplicity and intuitive design of the Safe Connect range align seamlessly with these participatory maintenance approaches, fostering a culture of engagement and vigilance. This workforce empowerment is a force multiplier in the quest for operational excellence, ensuring that comprehensive maintenance practices are imbued with a heightened sense of responsibility and proactive oversight.

The simplicity and intuitive design of the Safe Connect range align seamlessly with these participatory maintenance approaches, fostering a culture of engagement and vigilance.

Bridging the Gap Between Periodic Inspections and Continuous Monitoring

While periodic inspections are invaluable for maintaining system health, the transient nature of such approaches leaves gaps in monitoring that can be critical. The Safe Connect range effectively bridges this gap, offering a continuous monitoring solution that complements traditional IR inspections. By providing round-the-clock surveillance of electrical connections, these products ensure that the window of vulnerability between inspections is effectively closed, heralding a new era in preventive maintenance strategies.

Streamlining Operations and Enhancing Cost Efficiency

The operational benefits of adopting the IRISS Safe Connect range are manifold. By facilitating early detection of potential issues, these products allow timely interventions to prevent costly equipment failures and operational downtime. Reducing emergency maintenance and repairs directly translates into significant cost savings and operational efficiencies. Furthermore, the ease of integration and use of Safe Connect products reduces the need for specialized training, further enhancing the cost-effectiveness of maintenance operations.

Envisioning a Future of Enhanced Electrical System Management

Adopting the IRISS Safe Connect range of thermochromic products represents a paradigm shift in electrical system management. By addressing the limitations of traditional IR inspections with a continuous, intuitive monitoring solution, these products set a new standard in safety, reliability, and operational efficiency. Empowering operators through simplified, accessible technology promotes a proactive, effective, inclusive maintenance culture.

The Role of Continuous Monitoring in Future-proofing Operations

As industrial operations become increasingly complex and the cost of unplanned downtime grows, the importance of robust maintenance strategies cannot be overstated.

The Safe Connect range positions itself as an essential tool in the arsenal of future-proof maintenance practices. By offering a continuous, real-time monitoring solution, these products enhance immediate operational safety and efficiency and provide a scalable solution adaptable to industrial maintenance demands.

Sustainability and Environmental Considerations

In addition to operational benefits, the adoption of Safe Connect products contributes to sustainability efforts. These products help reduce equipment failure and unnecessary parts replacement waste by enabling more targeted and efficient maintenance practices. his efficiency aligns with broader environmental sustainability goals, underscoring the role of advanced maintenance technologies in promoting more responsible industrial practices.

By addressing the limitations of traditional IR inspections with a continuous, intuitive monitoring solution, these products set a new standard in safety, reliability, and operational efficiency.

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Conclusion

The IRISS Safe Connect range of thermochromic products emerges as a groundbreaking electrical system safety and maintenance solution. By surmounting the limitations of traditional inspection methods with continuous, user-friendly monitoring, these products offer an unparalleled blend of security, efficiency, and operational simplicity.

The empowerment of operators to actively engage in maintenance practices heralds a shift towards more proactive, inclusive, and effective maintenance models. As industries continue to grapple with the challenges of maintaining complex electrical systems, the Safe Connect range stands as a testament to the transformative potential of innovation, promising enhanced operational performance and a future of safer, more reliable, and sustainable industrial practices.

Author:
Martin Robinson
Founder, owner, and CEO
IRISS Inc.

Martin Robinson is the founder, owner, and CEO of IRISS Inc., a leading manufacturer of infrared inspection windows. Robinson focuses on innovation and is a pioneer of Electrical Maintenance Safety Devices (EMSDs) that help protect technicians from harm while protecting their companies' bottom line. He holds several patents for condition-based maintenance devices and has designed multiple maintenance programs that include infrared, ultrasound, partial discharge testing, non-destructive testing (NDT) and energy management strategies. He holds a NEBOSH certificate in Occupational Safety and Health, an IAM Certificate in Asset Management, is a certified Level III Thermographer, a Certified Maintenance and Reliability Professional (CMRP) and a Certified Reliability Leader (CRL). He is a member of IEEE, NFPA and is a standing member on the technical committee CSA Z463 guidelines on maintenance of electrical systems.

Anthony Coker

“

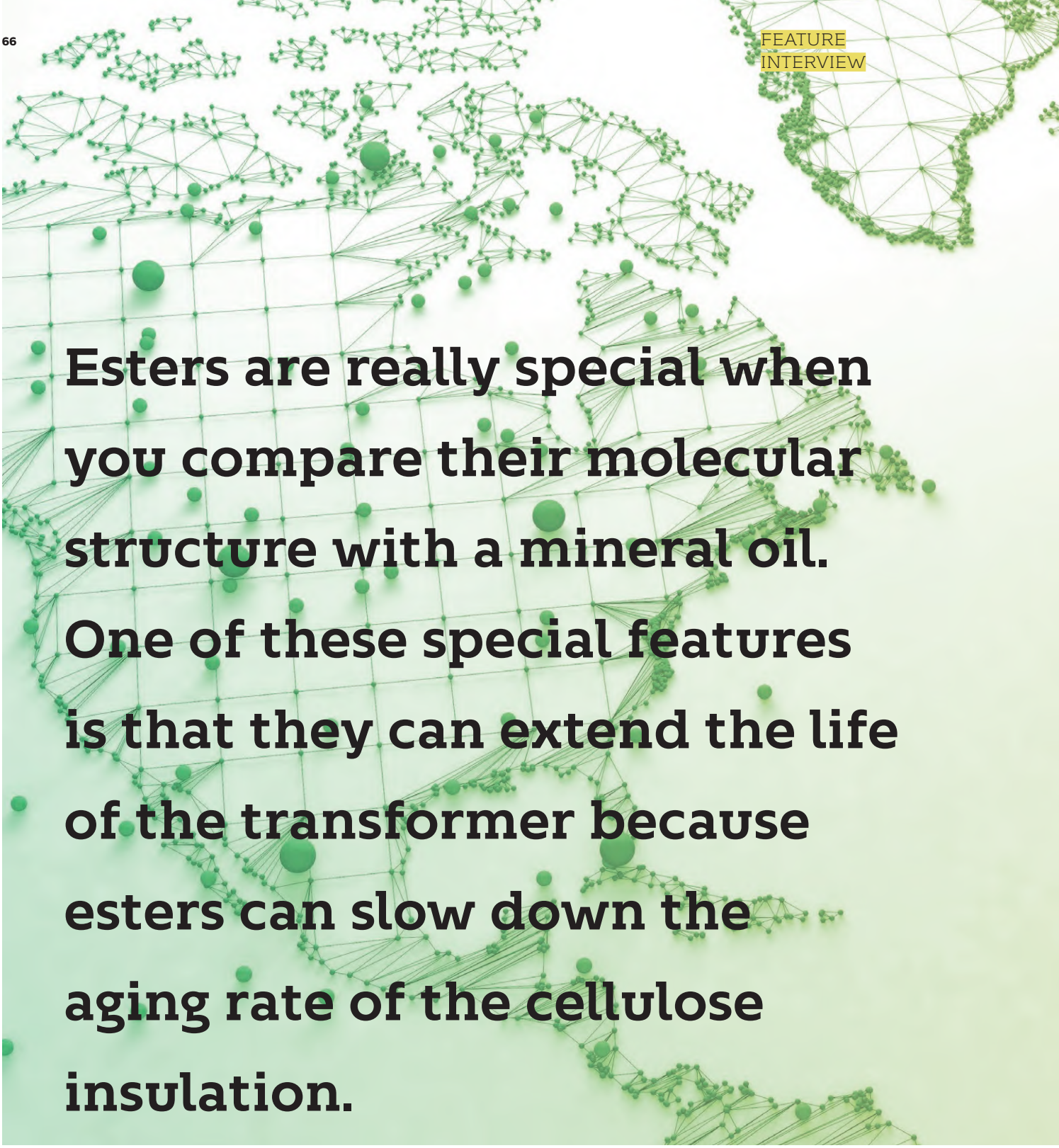
We are seeing growth in retrofills because it is difficult to source new transformers right now. Retrofilling is a smart way to maximise the life and the value of the asset. It's a far quicker and often cheaper way to achieve risk mitigation.

[MIDEL®]
MIVOLT®

Photo: Midel & Mivolt Fluids

Executive Vice President of the Americas
at MIDEL & MIVOLT Fluids Ltd.

Interview with **Anthony Coker**



Esters are really special when you compare their molecular structure with a mineral oil. One of these special features is that they can extend the life of the transformer because esters can slow down the aging rate of the cellulose insulation.

Alan Ross: My guest is Anthony Coker, Executive Vice President for the Americas with MIDEL & MIVOLT Fluids. Thanks for joining us. Anthony, talk to me about the adoption curve of esters and what is happening at MIDEL.

Anthony Coker: Yes, the adoption curve is a good way to put it. I don't think we are quite at a hockey stick inflection point yet, but it is a high growth set of products right now with esters around the world. There are a lot of suppliers spread around the globe. We've been in it for 45 years, so it is nothing new for us or the market. We started in Europe, where Synhtetic Ester MIDEL 7131 was patented and invented: when it was time to replace PCBs back in the mid to late '70s. The growth of synthetic esters started then, and decades later natural esters popped up regionally around the world, where you still see some strong regional players. But with MIDEL, we've been fortunate to be in both natural and synthetic esters for the last 20 plus years.

AR Really? I didn't know it was that long.

AC Yes. In both Europe, United States, and Asia for MIDEL. You are right, you did not see a great deal of us in the US

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probably until about six years ago. A lot of our big OEM customers said, “You're a globally used product, so we are taking you global with us.” We have big customers in the States and throughout the Americas that want MIDEL to be there, so we established a subsidiary in the US to support them like we have done in Africa and Asia.

AR What are the specifications that make esters the best choice for transformers?

AC That is a good question, because there are a number of parameters, depending on the application and the end user, the utility or the commercial customers’ needs at the time. It first started off with fire safety. A fire-safe fluid, an FM-approved fluid, that is UL-classified. Those were the main drivers. For a while biodegradability was just icing on the cake. Nobody really specified that decades ago. The world has changed since then, however. In some cases, engineers, companies, and utilities are now leading with, “We want it biodegradable. We want it non-toxic. We want it to be safe for flora and fauna.” That's driving it almost as much as fire safety now. Fire safety is still a big deal, though.

I want to continue to be the trusted advisor to these utilities and end users. I used to be just the ester guy. Now I can support where mineral oil suits the application best and where our natural and synthetic esters suit the applications best.

AR Deciding on specifying esters is no longer about size, right? Would you put a natural ester or a synthetic ester in a GSU?

AC Oh, absolutely! We have a giant project that is going to use all synthetic ester up on the Columbia River this summer, and it will be part of a green hydrogen project. All those GSUs are using synthetic esters for the first time and replacing mineral oil. Those are new units. Also, about an hour south of Sacramento, where we are today, there is a giant retrofill project as well, on waterways. It is pumped hydro, so you can get water pumping for storage, or you can generate with the GSUs off of that, and those are being retrofilled with MIDEL 7131 synthetic ester to replace the mineral oil.

AR Okay, so size no longer matters.

AC I would say you are right. Use cases needed to creep up in size and voltage and the designs needed to get there. Demand from utilities is pulling the OEMs higher and higher up to 500 kV. That's where we are now. That is going to be a lot more of the market with some of those bigger units, and there will be demand for even higher voltage classes than that coming in the near future.

AR Where were we 10 years ago in the acceptable size application?

AC You know, 10-20 years ago, it was probably somewhere around 69 kV.

AR You can see that difference. We need to get the word out because people still think you can't use natural synthetic esters. Retrofills are something that the industry, the users, are afraid of. But at the same time, it's happening over and over again. But the question I have is - why retrofill? Why would you suggest it to somebody who's already got a transformer?

AC Well, there are two main reasons: Fire Safety and Sweating the Assets. As we just heard from a couple of the experts in the industry at this conference describing how difficult it is with supply and demand imbalance right now. So, you look to keep current assets

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operating as long as possible today. How do you do that? That is a very expensive unit or set of units in that substation. Do I have to look at replacing them fully? If I am being required by my insurance company to make them fire safe or make the substation fire safe, put in firewalls, put in extra containment, fire suppression, do I do all that, or could I retrofill if the units are worthy of it? Or do I wait three or four years for new units? We are seeing growth in retrofills because it is difficult to source new transformers right now. Retrofilling is a smart way to maximise the life and the value of the asset. It's a far quicker and often cheaper way to achieve risk mitigation.

AR At this conference I just moderated a panel where we heard about people using high powered rifles to shoot at transformers, trying to knock out a substation. If you hit a bushing and you hit it just right, the oil under pressure can create a fire that cannot be extinguished. You just let it burn out.

AC Yes, the bushing is probably the weak spot to cause that fire. You are correct, but if filled with MIDEL, that would not be a fire safety issue on top of an active shooter issue. And, then your environmental risks from the transformer liquid, and also don't forget the fire fighting foam; are also mitigated.

AR Going back to retrofills a little bit, you mentioned getting more life out of a transformer.

AC Yes. You have a lot of money invested in them. How can you extend the life of a transformer?

AR How does a retrofill extend its life?

AC Esters are really special when you compare their molecular structure with a mineral oil. One of these special features is that they can extend the life of the transformer because esters can slow down the aging rate of the cellulose insulation.

AR Really? By percentages, do you have some data about it?

AC You cannot guarantee, in a retrofilled unit, how much more life you are going to get out of it, but you know you can slow down the aging rate. Now, on a new unit, we have had some utilities in certain parts of the world say, "We will go forward with this project with using your esters because we know we can get 20 to 25 % more life of that transformer", so it pays for itself easily that way.

AR Let's talk about moisture wicking, that an ester actually takes moisture out of the transformer. I believe the life of a transformer is the life of the paper and moisture in a transformer degrades the paper. Talk a little bit about that, about moisture in a transformer.

AC Two things occur with moisture in an ester-filled transformer. First, in mineral oil, oil and water separate, right? In ester, again, the magic molecule, it has a hydrogen bonding property with water molecules. You get the hydrogen bond of the H_2O with the ester double bonded oxygen, and you lock up the water in that solution. And it's not a separate solution, it's in the ester. You can do that to a certain percentage. For instance, with a synthetic ester, you can go to a very high water saturation level, approximately 2,500 parts per million. At high water saturation, it is still the great dielectric liquid which you originally asked it to be, but it has also been able to grab the water in the unit in comparison to mineral oil.

And second, where is some of the water coming from? The water is a breakdown characteristic of that cellulose aging. If you can grab the water away from the paper, you have accomplished this: It slows down the aging rate because it binds to the water. And water is a catalyst for more cellulose breakdown. So you have the ability to bind water in solution and thus decrease cellulose breakdown.

AR Talk to me a bit about that break down.

AC The cellulose molecule itself will break down in a mineral oil or ester environment, any environment, even inside a transformer, even if it is sealed, it is going to see a little bit of oxygen, a little bit of a moisture, and a maybe a lot of heat. Those things help break down that cellulose chain. When it breaks down, it gives off some other different molecules. It gives off short-chain fatty acids, long-chain acids, and water. If you can keep the water from going back and catalyzing that reaction by holding it in the ester, you slow down that reaction. That is one of the keys. Also, we have actually seen in marine environments, and applications on shipboard where they use synthetic ester because it can actually help dry out the transformer. Some of the first retrofills that were ever done in England were at naval dockyards, where they had wet transformers, and they used it to retrofill and dry them out.

AR Do esters have a better capability of handling heat? For example,

if you're in Texas in July it is hot, and you need to operate those transformers above rating. They're at 120% or even 130% of rating longer than normal. Do esters handle it as well, better, or worse than mineral oil?

AC If we could draw a curve right now, a heat vs. time aging curve it would show that when the cellulose heats up in the transformer, the life of the insulation is reduced. It ages quicker and we lose time from its initial lifespan. If you run the cellulose in ester hotter, i.e. operate the transformer at higher temperature, you can get the normal amount of life out of that transformer that you would with mineral oil, or you can run it at a normal top load temperature that you would with mineral oil and get the extended life. That is actually how you can dial in loading and temperature with esters. I can run them hotter. I can safely short-term overload them better. I can design in a little bit of overloading. That is what some of the utilities are looking at right now. It is another feature.

AR Owners must be looking at this because their assets are being asked to do more consistently and constantly. Last question is what does the future look like? Other than growth, what does the future look like?

AC We are currently a member of the Shell Group as a portfolio company, but are on the path to being integrated into the global Shell business. We were a smaller British company, privately owned - now we are part of a major global company. Together we have some great capabilities globally. You will see a lot of these come to bear for our global customer base right across the markets we serve, particularly around logistics, supply chain and capacity.

AR You know, one of the things I thought when I heard this is that it is almost counterintuitive that an oil company invested in and bought a natural and synthetic ester company, one of the oldest leading synthetic companies. It appears that it just gives Shell

Photo: Shutterstock, Midel & Mivolt Fluids

the ability to offer more to customers than they did before.

AC I think you just hit the nail on the head. I feel being part of that wider Shell family is great. MIDEL has always been in the position of being a trusted advisor to utilities and end users in selecting the right ester type for the job. The same is also true for Shell in pioneering its gas-to-liquids (GTL) technology, by the way. Going forward, being part of a leader with a broader portfolio of products will only increase the value we bring to the global transformer liquids market.

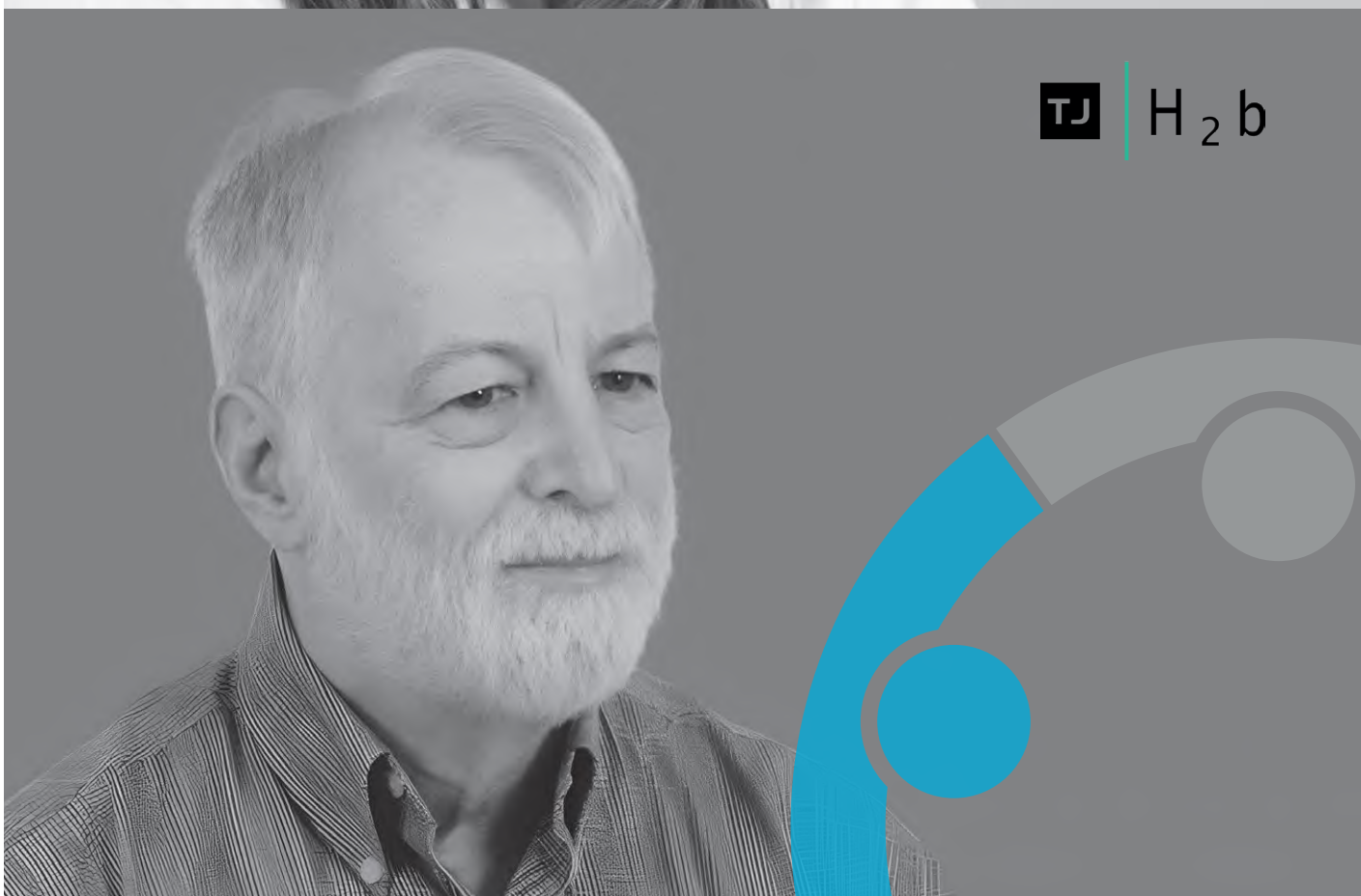
AR Because until now, I has been a battle between the two. And now what you're saying is, this is no longer a battle. This is what is best for the industry.

Anthony, thank you so much.

AC Thank you, Alan, I appreciate the opportunity to share with your audience.

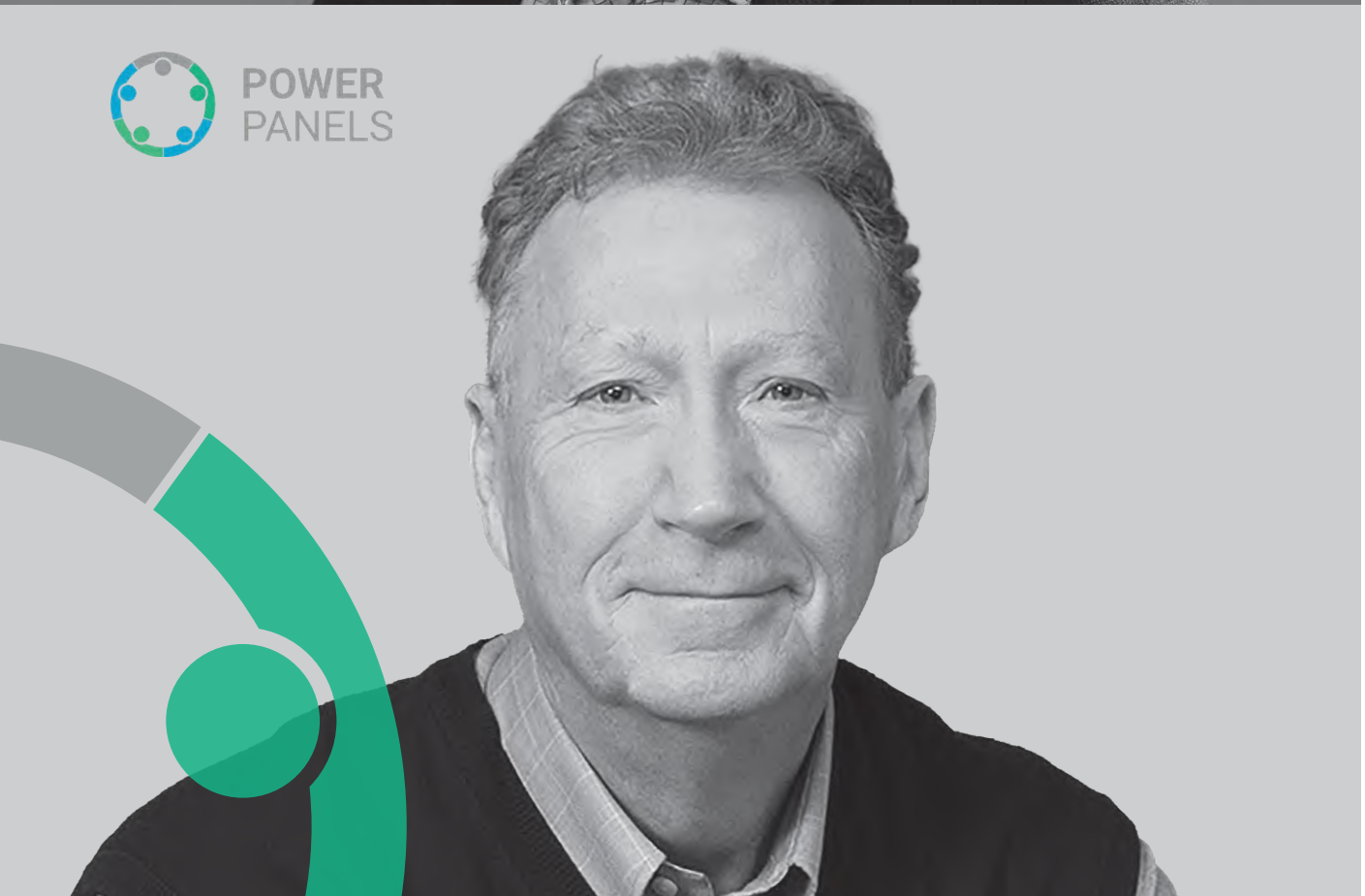
POWER PANEL DISCUSSIONS

Javiera McGuiggan
Assistant VP & Global Business Director, Cargill BioIndustrial



Claude Beauchemin
Director of Technical Development, TJH2b

Insulation Systems – Oil, Fluids, Solids & Cooling Systems



Thomas Norby
Technical Manager - Lubricants and Electrical Industry, Nynas AB

Alan M Ross
Managing Editor, APC Media

> It is a unique time, with incredible accelerated growth and demand for the power industry that you would think was super-established and very traditional. Add to this the sustainability push, which in our case has been a key driver for trying to look for different options and very aligned with the renewable energy industry.
>
> **Javiera McGuiggan**

Alan Ross: I would like to thank our guests for joining us on this edition of our APC Media Power Panel, Javiera McGuiggan from Cargill Bioindustrial, Thomas Norrby from Nynas and Claude Beauchemin from TJH2B. Thank you all for being part of this. Before we get started, if you would just briefly tell us a little bit about yourself and your background. Thomas let's start with you.

Thomas Norrby: Thank you, Alan. I am an organic chemist by training, and I have worked in the lubricants and oil industry for about a quarter century. I work with Nynas for dielectric fluids for insulating for the electrical industry. I am active in IEC and CIGRE environments and I work closely with our key customers in the transformer OEM industries, and also with the utilities. So, it's very nice to be here today and to share a few of our thoughts and experiences from the field.

AR Thank you, Thomas. Javi, I see your FR3 fluid logo behind you?

Javi McGuiggan: Yes, thank you, Alan. I am the Global Business Category and Assistant Vice President of Cargill Bioindustrial- Power Systems. I have been leading the power systems business with dielectric and cooling fluids within Cargill for over five years now. I originally am a Hydraulic Engineer who ended up in very technical but still business-related jobs for my career. I am the Commercial Leader, and I also have the technical team under me. We have the beautiful mission of turning some of our derived nature chemistries

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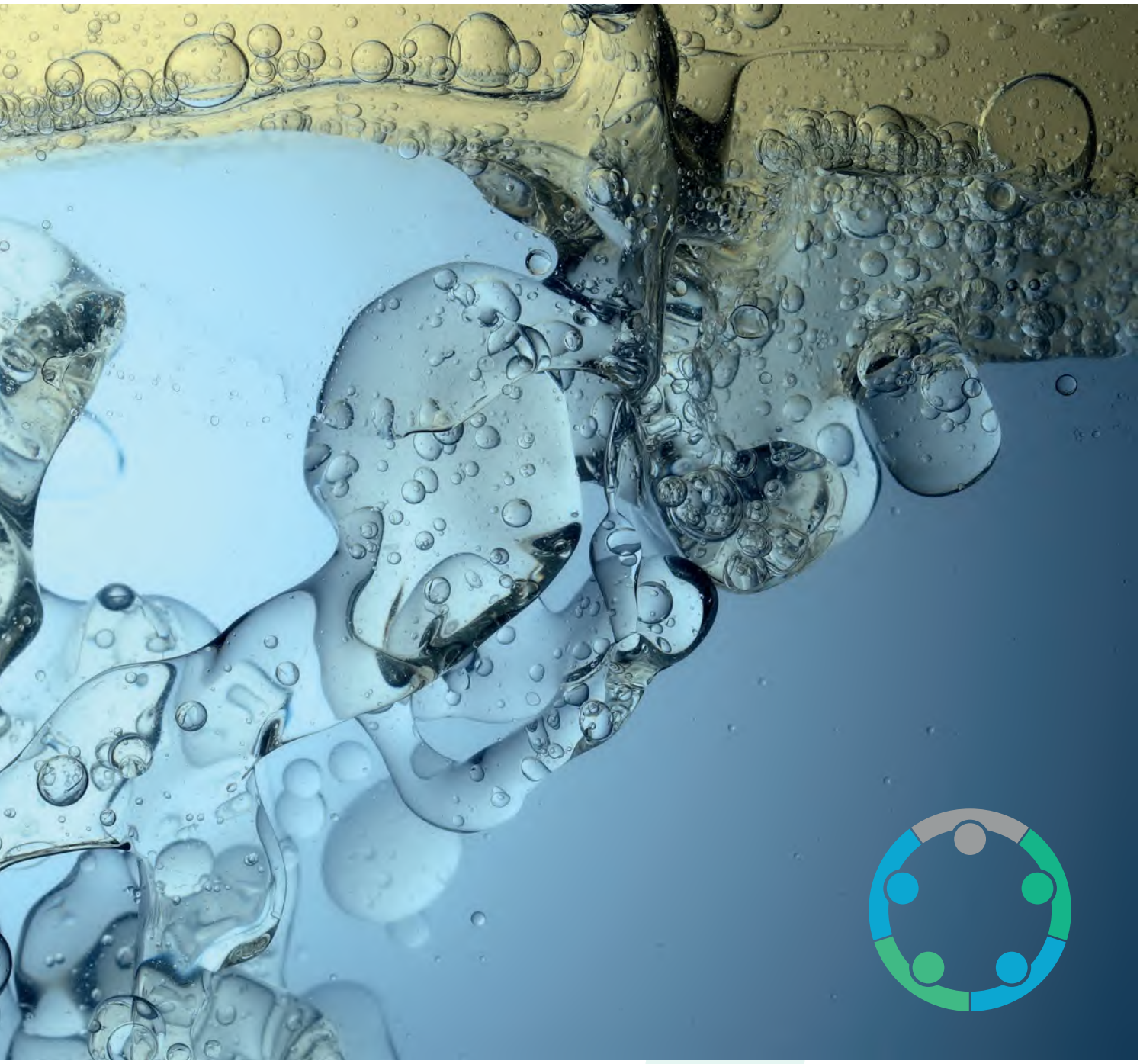

from renewable resources into industrial applications. And of course, FR3 fluid is one of the star products of Cargill Bioindustrials.

AR Thank you, Javi. Claude, you are with TJH2B and one of my go-to people on lab testing for transformers.

Claude Beauchemin: Thank you, Alan. I am a chemist by training, but I have been involved with electrical engineering all my life, so I live between two worlds. I have been working for 45 years in transformer and transformer insulation materials. The first part of my career I was involved with online monitoring. I was part of a company that introduced online monitoring and transformer management, and I moved to TJH2B 14 or 15 years ago now. The bulk of my job today is more on the interpretation side and the specification side, than on the analytical side proper. TJH2B also puts on the TechCon Conference every year, which I am part of.

AR Thank you, Claude. By the way, I think TechCon is one of the best technical conferences I attend every year because it is very utility-focused. It is a great conference, and I think it is in my hometown of Atlanta, Georgia this year, correct?

CB Correct. March 3-5, 2025.

AR Yes, I will see you there for sure. The first thing we want to do before we talk about oils and fluids, even though that is

our topic, is to get your perspective on where we are relative to transformers in Europe, UK, and North America. Let's start with you, Javi.

JM It is a unique time, with incredible accelerated growth and demand for the power industry that you would think was super-established and very traditional. No one is surprised by the growth anymore. We have been living through that since COVID. I think what we are all working on now is staying close to our strategic accounts and our OEM partners, to really understand market dynamics and how long this growth is going to last.

We just heard a study projecting 5X growth for transformers in the next five years. That is almost an absurd level of growth where we must get multiple resources in balance. Overall, our partners and customers say, "We knew the wave was going to happen, we just didn't know everything would happen at the same time", meaning aging grids, the expansion and creation of grids where you have newer population or growing or more developing countries, the electrification of everything from water heaters in California to, of course, vehicles.

Adding to this is the sustainability push, which in our case has been a key driver to explore different options and closely aligned with the renewable energy industry. So, we have seen noticeable shifts from supply and demand being so unbalanced with more developing regions like China, India and Korea, moving into higher levels of penetration in markets like Europe and North America. Very smartly, those regions are investing in expanding capacity and expanding plants. It is not something that happens one day to the next, but hopefully gets us to a better and healthier balance between demand and supply.

AR Thank you, Javi, great insights. Thomas, your thoughts?

TN We share much of the same opinion. It is interesting to see mature industries suddenly being yanked from 2% to 5% yearly growth to multiples of that or even 5X, which is FinTech or IT type numbers. Of course, when you have to build hardware and actually have physical products, that is not going to happen rapidly. What we have seen, the European OEMs have invested wisely in production capacity in China, Vietnam, South Korea and India. Many of these units are coming back to Europe and even more so to North America. We also see the big local South Korean super brands like Hyundai. From our perspective we see a lot more interaction with many, many more OEMs and also huge orders driven by the things that Javi just mentioned. But I really want to underline the huge impact of renewable energy in large offshore wind

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installations such as we have around the North Sea. These are absolutely massive Apollo-type projects. It's like putting a man on the moon. They are completely rewriting the story about energy around the North Sea.

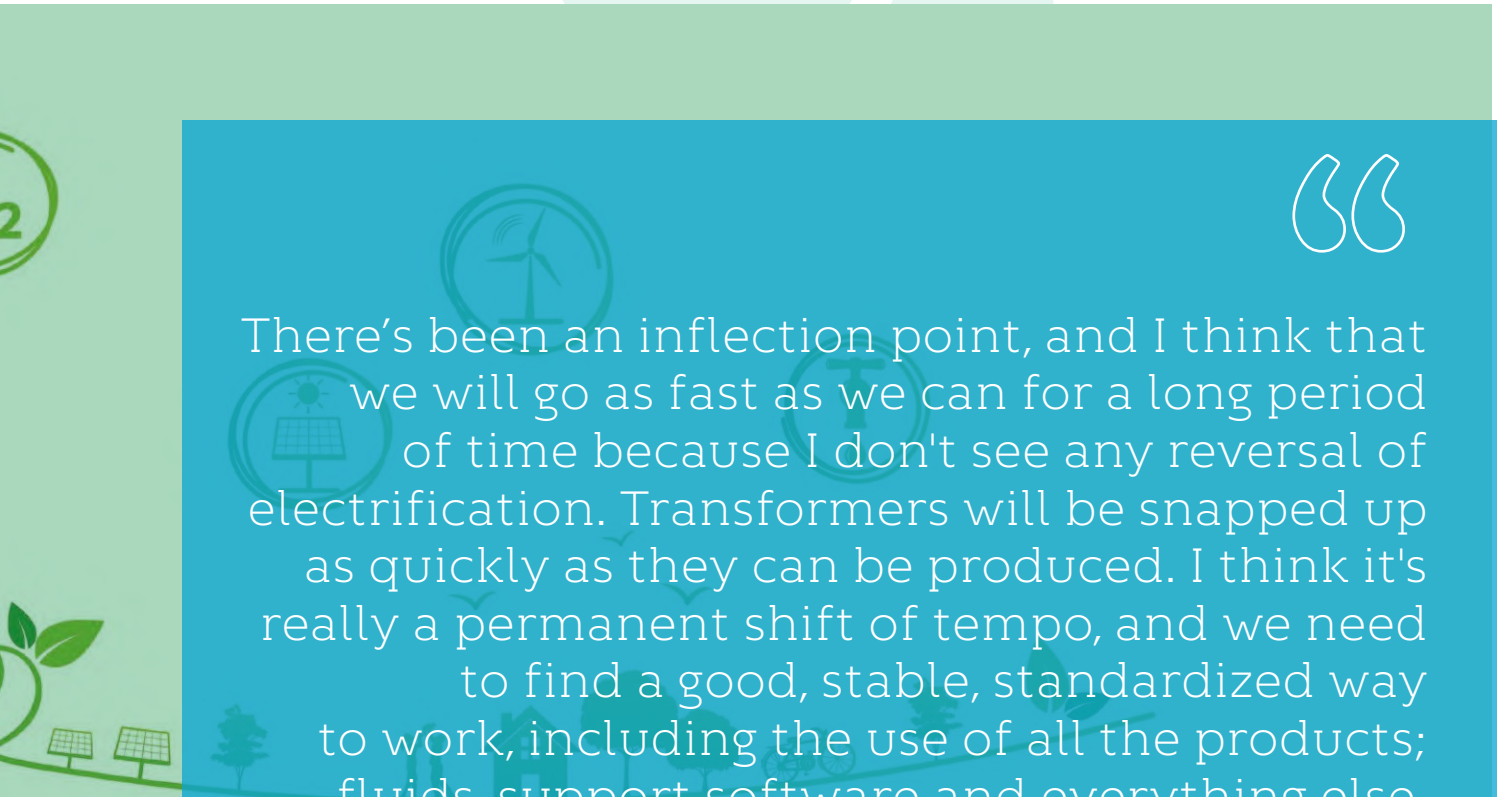
For example, in the North Sea, the traditional oil and gas industry is slowly shrinking and the move to offshore wind is absolutely massive and we believe it will be sustained, because it will take such a long time, decades. Yes, I believe there's been an inflection point, and I think that we will go as fast as we can for a long period of time because I don't see any reversal of electrification. Transformers will be snapped up as quickly as they can be produced. I think it's really a permanent shift of tempo, and we need to find a good, stable, standardized way to work, including the use of all the products; fluids, support software and everything else. So, it is a really important time for the industry, right? Can we deliver?

AR Thanks Thomas. Claude, you see it from a different perspective. You see it from the standpoint of the existing infrastructure and all of this new infrastructure. What are your thoughts about the transformer market?

CB Well, it certainly is an interesting time. Of course, my perspective is more on the material going into a transformer than in their quantity. But even the increase in the quantity will challenge the laboratories around the world. We will have to add equipment and people. Equipment is easy, with people sometimes it is another story. I have to say that since I got into the industry 45 years ago, I've seen a lot of changes. It was effectively, initially, a very traditionalist industry. Nothing was moving. Everything was taking forever. At some point in time, we started to see some pickup in the pace of evolution development, and today it's really active. While we are talking about liquids today, the same thing is happening on the solid material side. One of the challenges that the analytical side has to address is the evolution of interpretation. We used to see information that meant something was good or bad, and now the interpretation has evolved as the material evolved. For example, for gas in oils, traditionally we focused primarily on hydrogen and acetylene.

Now we have new liquids, and the interpretation is a bit different, and we have to be careful. What used to be a level that created panic will now be normal with another liquid, and the reverse is true as well. There is an evolution taking place, like the push for vegetable oils is growing.

The amount of demand for energy is tremendous. Will it be satisfied?



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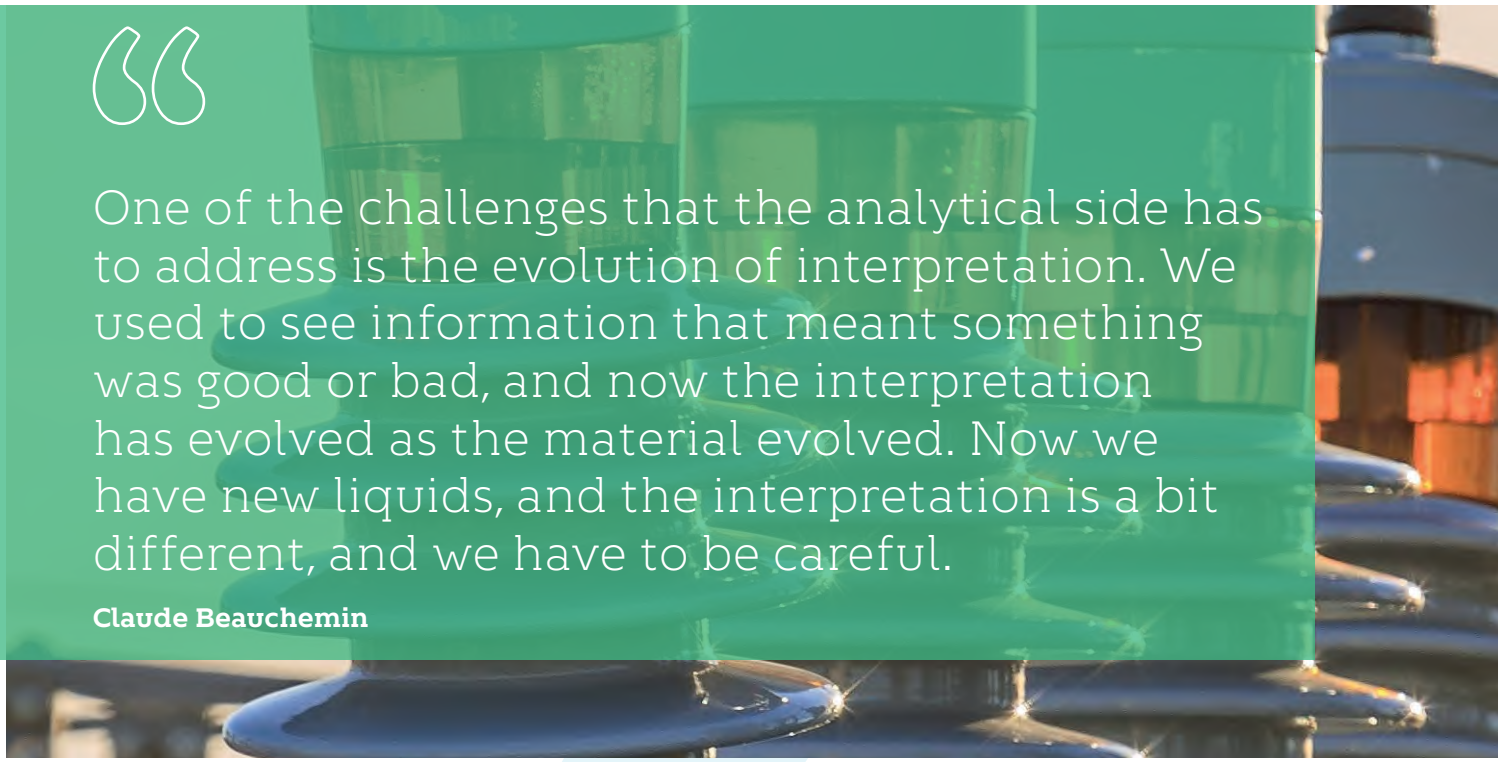
> **Thomas Norrby**



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>
> **Claude Beauchemin**

That remains to be seen. One thing for sure is the demand on the equipment is increasing. Because the demand for transformers is increasing and the supply is restricted you need to keep existing units operating today for longer than expected. When I was new in the field I was talking about mineral oil because it was the only thing available at the time. When the mineral oil was degraded enough, the situation in those years was to replace it, send the used oil to the boiler rooms, burn it, and just put new oil in the transformer. It was disposable.
It was acceptable then because it was inexpensive, but it is no longer acceptable today.

JM I love Claude's comments because he is such an expert in oil analysis. We, with natural esters, are still the new kid on the block, even though we have been in the industry for almost 30 years. We always use that quote from Einstein, "Everyone is a genius, but if you judge a fish by its capacity to climb a tree, it will live its entire life thinking it's a stupid animal." That is what we need to get over.

AR Einstein said that? That is funny. There is a learning process that the whole industry needs to do. Thomas, we will start with the following: Protect me. I am a transformer owner, and I cannot buy them fast enough to replace the old ones. How do I avoid an unplanned outage, and what should I be aware of?

TN The noble art of asset management is becoming even more important today. If I were responsible for asset management, I would make sure that I train and retain my key staff so that I have people out there who know what they are doing. Taking care of the equipment as Claude said, interpreting the analytical data correctly to, let's say, turning every stone and realizing that the value of the systems which are up and running is actually probably greater than you think.

There was also some interesting news at the Paris CIGRE sessions this summer. One of the keynotes was from Professor Werle from the Institute of Electric Power Systems about some recent findings on how these renewable energy transformers are doing; what is happening with the type of generator. It is now so big, massive, with like a million new transformers in the field that the problems are starting to show up in the statistics. There are differences which are not so subtle when you have lots of harmonics and transients. While this has been known, we are now starting to see how it plays out in the field.

AR Claude, talk about this same thing, how do you help utility managers avoid unplanned outages?

CB The idea here is to try to detect early warning signs that may indicate that something is degrading and needs to be investigated. When we must replace a transformer, the main problem, today, is that the replacement transformer sitting on the pad "just in case" that used to be there is no longer there, because we have that pressure on supply and could not have made idle units anymore. The way to help is the same as in the past, but maybe we speak a little bit louder now; is to interpret the signs. Try to see if you can

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extract from those signs given by analytical techniques or online monitoring of a possible issue, to see if this is rising fast or slowly, which is not obvious by any stretch of the imagination, and then educate the end users about its signification. As an example, we have methanol as a way of looking at paper degradation now, where we used to have only furan. It is a question of education. We have to be in the loop to educate and give tools to the operator to interpret what we see.

AR Javi, same question.

JM All I'm going to say pertains natural esters. In my campaign that states esters as a name, synthetics and naturals are very different animals themselves. Natural esters is what I am going to talk about. Thankfully, and this is one of the reasons why naturals have grown so rapidly lately, is that we provide a couple of technical reasons why you get almost a little insurance to prevent failures. The first thing is that, in the past, units that were aging needed to be replaced. If you had the availability of new transformers, you would have just replaced them. The oil change to FR3 fluid, the molecule of vegetable oil, in particular soy, is very long and it engages part of molecules that could be in the transformer from moisture or free water, trapping it. By trapping part of the water molecule, it keeps it away from the solid insulation. With solid insulation staying dry, you are effectively prolonging the life of a unit. Secondly, some utilities are using a new concept of dual rating in transformers, even though the standards are still in development. We already have some utilities in the US utilizing this concept of having the same size of a nameplate unit, but knowing that because of the more than double flash or fire point in natural esters, you have this built-in risk that if you have a low load that's higher than what you had planned for, that is, you have plenty of capacity with that same unit. That is, again, much like a safety insurance thing. Or in the case of supply availability, you can buy one size of transformer that now can serve more than one function. Now you could use the same unit for multiple purposes until you can get more transformers. Again, it is a concept that is still working through IEEE, of dual rating nameplate to give you this access to a heavy load or unplanned peaks, is some of the things that we are seeing.

In Europe, it has a different name. The concept of using that higher temperature rise capacity goes more under something called SPL or sustainable peak load instead of dual nameplate rate. It refers more to building an efficient, smaller, more compact unit, so you get the advantage of using less of the other more expensive ingredients, components of a transformer, and making a smaller unit to get the same amount of power. These are some of the things that you can do with esters to address the crisis of supply and demand.

AR Let's discuss the impact of overheating on the paper, because the life of the transformer is the life of the paper. The oil protects the paper. The life of the transformer is the life of the paper. Talk a little bit about what you're seeing and the growth of the esters, natural and synthetic esters.

I am familiar with a lab that had a 1% annual growth with testing of esters, then it had a 1.5% annual growth until it had a 2%, just in the testing that they were doing. So that indicated the number of new ester-filled transformers in the market. Talk a little bit about what you're seeing as it relates to the oil, the fluids, and the paper.

JM As you know, we always talk about how conservative this industry is. I feel this topic of working with high temperature and high heat, either the dual nameplate or the sustainable peak load concept, is new. They're innovations in this world that have been a little more pushed and accelerated because of the super unbalanced demand and supply that we have. I think we will learn more and get maybe more comfortable as we learn more about these concepts, but they are newer. And there's a great study of our friend Fernando from the Copper Association, he always shares the analysis of the load losses, high load, low load and no-load losses. He has a whole paper and analysis that he presents at conferences.
At the end of the day, we hopefully need to start looking at the overall benefits and limitations together, not just the limitations, because it's an innovation. It's a push for change, but we'll learn more.

AR Most retrofilling cases are required to be done on site. What are the key parameters that need to be checked to ensure that retrofilling on site would not be a risk for an unplanned outage?

TN First thing to be checked here is if you really need a retrofill. Check very carefully your business assumptions before any retrofill. Most of the times what we are seeing in practice, namely in power transformers throughout the backbone of the electrical grids (at all voltage levels), is that reclaiming the in-service fluid is more than sufficient to give the desired additional boosts to the technical lifetime of the liquid and of transformers. Minimum disruption is still an "innovative" approach for such a risk averse and critical activity/industry.

If a retrofill or oil change is deemed necessary, the requirements would be similar to other industrial lubricant systems. Ideally, you will have the time and opportunity to take a sample of the transformer oil that is in the unit.
You can test it according to IEC 60422:2024 and make sure you understand what condition it is in. Then, do a miscibility study with whatever you are wanting to put into the transformer. Ideally, maybe you can get 95% of the old oil out, but the sludge will be impossible to get out.

You need to look at the range of blends, ideally, to see if 95% is good enough, if you're happy with the results you're looking at 95%. Usually, there's a sharp transition at some point when, let's say, the benefits of the new clean oil will dominate the problems and wipe them out.

Oil analysis and miscibility, unfortunately, is time consuming and costly. It is the only way of reducing the risk significantly. Then there are other very simple things like readings on the nameplate, finding someone who remembers what was actually in the system and having analytical tools to support your decisions.

There are a lot of good guidelines in the 60422:2024, and I'm sure there's the corresponding one with IEEE. Guidelines are there on how to do it. Read the instructions.
Try to fill it up with an oil which is supposed to be compatible, that reduces the chances of nasty surprises for sure. But you have to read up on it and try to figure out the documentation or get testing if there is no documentation, right?

JM I would only add that the process itself to keep the process of retrofilling safe, the guidelines and recommendations, is pretty similar for both oils. There's a new particular standar on retrofills being worked on as we speak, for IEC in Europe, that is going to add better cautions or more detailed explanations for esters in particular. The process itself is not that different. In general, we always get a question of how much mineral oil is left and if it affects mixing it up with natural esters. And the question is, after the proper cleaning process, heating things up and cleaning them up properly, is there always going to be about 3% to 5% of mineral oil that's still in the system because that's what it was usually operating with before? That is perfectly normal, and it doesn't affect the function of the transformer later. But we have been very fortunate to have great partners in our retrofil channel in the US, and they have never reported a failure after a retrofil, so we're very happy to say that.

AR Javi, we are going to end with a look into the future. What does the future at Cargill Bioindustrials look like?

JM I believe that our mission of what we do in Cargill Bioindustrials is beautiful. I am very happy about all of the businesses that are trying to grow from nature. Renewably derived chemistries in the industrial world are having a great moment, which is a great thing for all of us. Overall, what we're doing is trying to keep pace; trying to keep up with the

speed of growth on top of the supply-demand imbalance that is in the dramatic, accelerated global growth in the industry, as we discussed earlier. We know how important it is for people, especially after COVID, to have that security of supply, the certainty that it is the same product everywhere, that it has the quality that it needs to have, no matter what plant it came from, because if one has to shut down, we will have the backup system to keep providing customers. So, we are working extensively on the expansion of our current plants. We have more than seven plants now and we are working on other expansion projects to be able to keep up with that growth.

But I think the most important message that I want to leave with is that this beautiful wave of growth of the energy. The world just needs us to do better and more for cleaner and better energy. There is also a push in this traditional industry to look into new things and to be forced to innovate. You have two paths. You could say, "Keep the status quo, I will stay with what I know." But the world is pushing you to look into these innovations like natural esters or high heat or whatever comes next.

We are also very focused on teaching everyone that not all esters are the same. There are going to be a lot of new players coming into the market, so how do you learn how to evaluate them and trust them and still keep your knowledge and education up to date on all the confusion that might come? That is what we're working on at the latest.

Finally, sustainability is another area we are working on, developing a transformer sustainability evaluation, not for just the fluid. Moving from just the fluid carbon footprint to what is the full transformer carbon footprint and answer how do we make it better.

AR Excellent, thank you Javi. Thomas, what does the future for Nynas look like?

TN We do not manufacture esters ourselves, since they are a completely different value chain. Nynas is supporting the sustainable transition across the industry for the specialty products that affect people's lives every day in electrification and road infrastructure. It is a very key product for society now and in the future. Our specialty is refining non-fuel molecules into high performance, long-lasting specialty products.

We operate across international markets with a strong focus on Europe because we are based here in Europe. We work with the customers to create solutions and find new pathways forward to technical issues. With the transformer we have a long list of wish lists and customer asks. Keep lowering the carbon footprint in the production process. That is something that we are doing very actively with bio-based electricity and also green hydrogen very recently. It takes a big bite out of the carbon footprint. Also, we are working on scalable production to keep up with a very rapidly growing demand and to maintain the supply of our products which are readily recyclable. We hope to see some growth of re-refined products also in our application, although it is still very small. We want to keep it easy for the manufacturers and the owners or operators, keep the valuable and trusted fluid miscibility and material compatibility properties intact.

We are also working on new products with extended cooling properties and lower viscosity to provide better ability to handle load swings, harmonics, and increased voltage fluctuations with the low inertia grids of renewable energy, which is a rapidly rising issue, products that allow the same design principles and OEM practices to keep it simple and keep it scalable and keep it affordable so that this magnificent growth can materialize.

AR Claude, I am going to let you finish, what is going on at TJH2b?

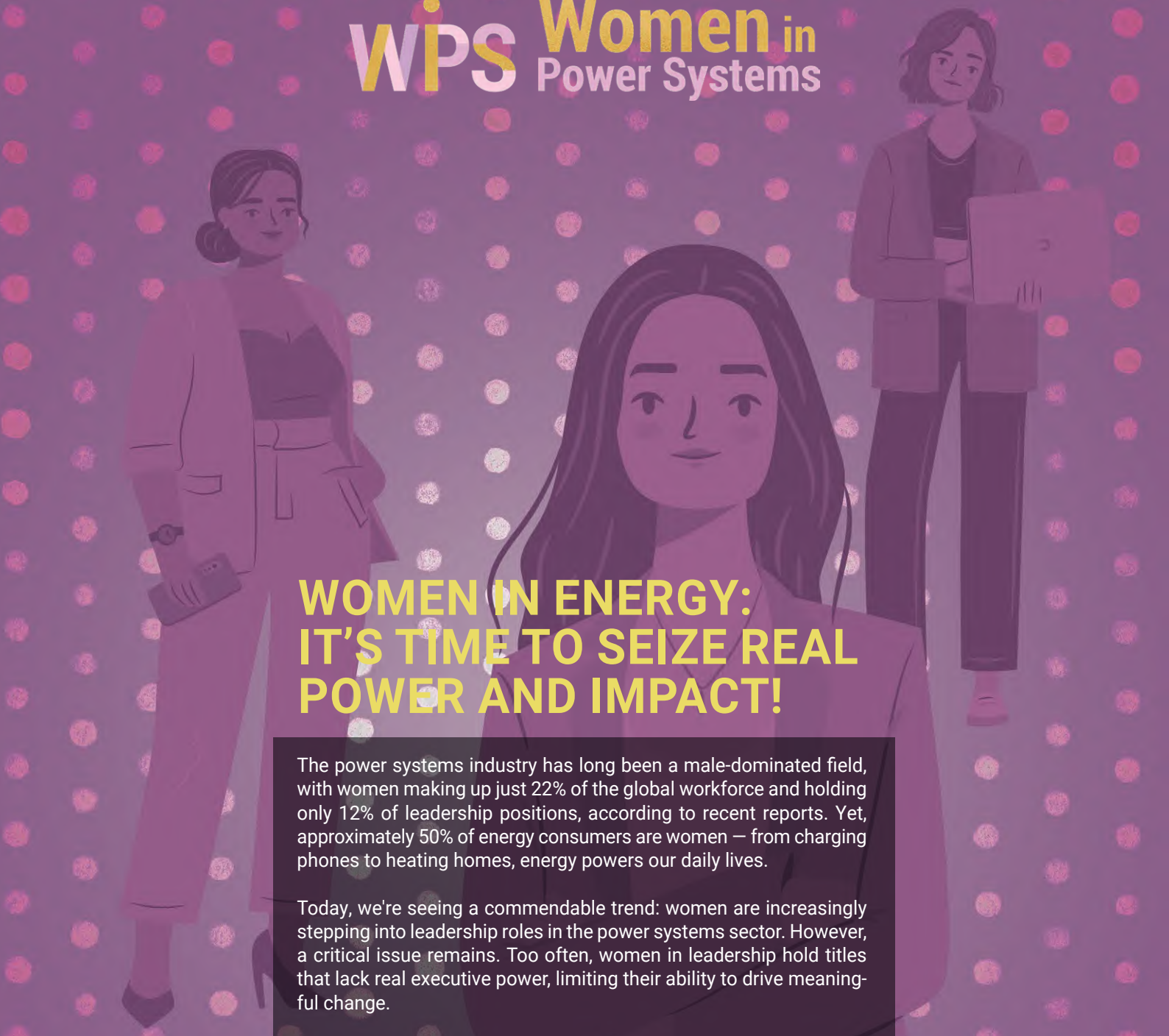
CB We have our worldwide group of laboratories, and as I pointed out, it is a learning process with these newer materials, these new situations, and we will keep abreast of it. We keep studying, we keep learning, we keep interacting with our customers, trying to help the customer. In turn, the customers help us with new cases and new things to look at.

AR Thank you to all our guests on this Power Panel. You all bring such great insight into the industry.

POWER PANELS

Editor's Comment:
Watch the full recording of the discussion at this link: Power Panel Discussion - Insulation Systems, Oil & Fluids, and Cooling Systems.

WPS Women in Power Systems



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Support and elevate the voices through Women in Power Systems.

Contact Managing Editor: Tamara Marček tamara.marcek@apc.media

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