ISSUE 24
December 2022
transformer-technology.com
ISSN 2642-2689

TRANSFORMER TECHNOLOGY MAG

TRANSFORMER TECHNOLOGY MAG

DIELECTRIC OILS & FLUIDS

PART 1

Interview with **Rainer Frotscher**, Maschinenfabrik Reinhausen
Interview with **Marta Reinas** & **Margarida Figueiredo**, Amorim Cork Composites
Interview with **Johan Fournel**, GMT International & Akhelec

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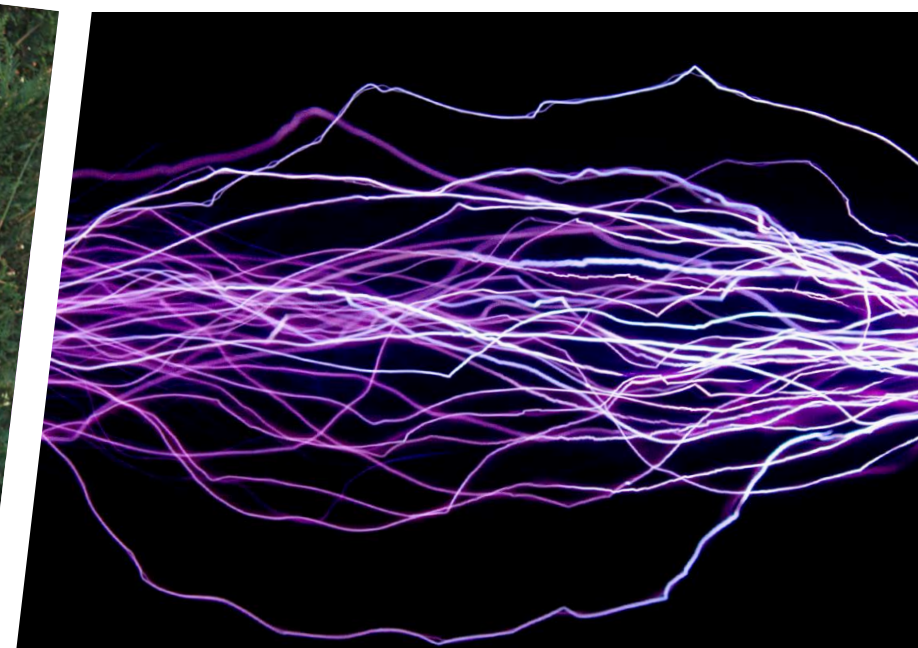

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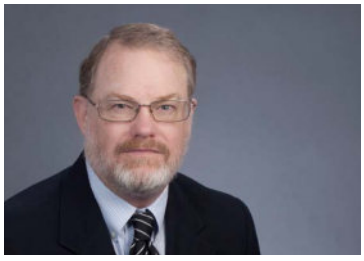

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ISSN 2642-2689 (Print)
ISSN 2642-2697 (Online)

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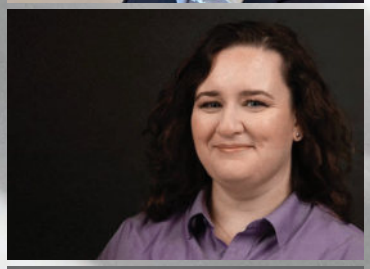

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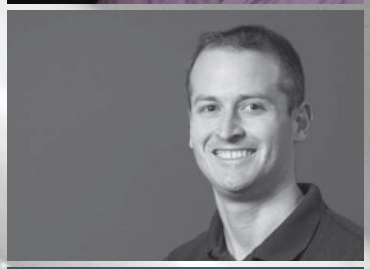

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Dear Readers,

"Well Magoo, you've done it again." This frequent quote, offered up by Mr. Magoo of the old cartoon franchise is one of my favorites whenever I inadvertently take what could be chaos and turn it into gold, much like the annual focus on Oils & Fluids. It was, and is, a tremendous team effort. When we invite subject matter experts (SME's) to share their thoughts and ideas about the topic of insulating systems and fluids, little did I realize how much has changed in the space and how many qualified experts would jump at the chance to write or be interviewed. So much good content was available that we decided the annual issue would be delivered, once again, as a two-part issue, once in December and another in January 2023.

Two topics seem to take center stage: Things in oil, like moisture, gases, inhibitor, and green oils and fluids; a subject that grows with interest as natural and synthetic esters grow in popularity. I have enjoyed conducting most of the interviews with our SME's and while we must cut down on the back and forth between me and my guest once the transcription is edited, if you have the chance to watch the archived video version, please do so since it will bring the interview to life and give you a greater appreciation for the expert credibility of our guests.

As for technical articles, once again our Technical Advisory Board members have come through. Their unique ability to bring technical knowledge to life in such a compelling way is a delight to all of us at APC Technologies and for that we are tremendously grateful. Writing an 1800-word technical article with supporting graphs, charts or pictures is not an easy task. Publishing them is even harder given the adage, *"Doctors bury their mistakes and publishers print them."*

Fortunately, we can adjust for our mistakes but due to the nature of digital publishing, the mistakes can live on forever.

I want to move past the two oils & fluids issues and onto something dramatically different for February 2023 when our theme is the Green Energy Revolution. I am as excited about this pivot as I have been for anything we previously provided for our Transformer Technology (TT) Community and for our commitment to Women in Power Systems (WPS). These past four years have been a labor of love for all of us at APC Technologies, a Division of APC Media.

When we made the decision to expand our focus into Power System Technology (PST), it came with a great deal of hesitation and pushback from some of our staff, all to preserve our great work focusing on transformers. Since I love metaphors as a means to develop a better understanding of a complex topic, I decided I needed a better way to explain the changes.

Transformers are like engines in vehicles. Power systems are the vehicle, but they make up a whole system of transportation. We can report on sport cars with their very unique engines and capabilities, and we can focus on 18-wheelers, or pick-up trucks, or SUV's. All are part of the system we call transportation, and all have engines and components that drive the system. (Pardon the pun please.)

Well Magoo, you've done it again.

As we expand our offering to the community, we will never abandon reporting on the heart of the power system, the transformer. We will add to it, great interviews and articles on the overall system that transformers support. Since there are so many changes taking place in power system technology, with the advent of Distributed Energy Resources (DER), Smart Grids, solid state technology and green energy to name just a few, our growth in this area is only natural.

Which brings me back to the impetus for the February theme, the Green Energy Revolution. At the Renewable Energy, RE+ Conference and Expo in Anaheim, California, we were able to interview 29 SME's and thought leaders and I am tremendously excited about all the innovation and development taking place in this space, so much so that I want to feature some of these interviews, and articles from those I was not able to interview. While much of the issue content has been planned, there is still room for long form Technical Articles and short form Perspectives. If you have an idea for a topic, please contact me directly at alan.ross@apc.media and give me a brief description of a topic you would like to present.

As I write this, we are celebrating a uniquely American holiday called Thanksgiving. It allows me time to reflect on those things, people, and events I am most thankful for and one of those is you, our APC Community. It is because we publish to our audience of so many, I never lose site of the fact it is a privilege and honor to do so, and we will faithfully continue to bring quality news, technical information, and great interviews. I am also thankful for a wonderful staff at APC Media, without whom we could do none of this.

Be blessed and thank you.

Alan M Ross
CRL, CMRP
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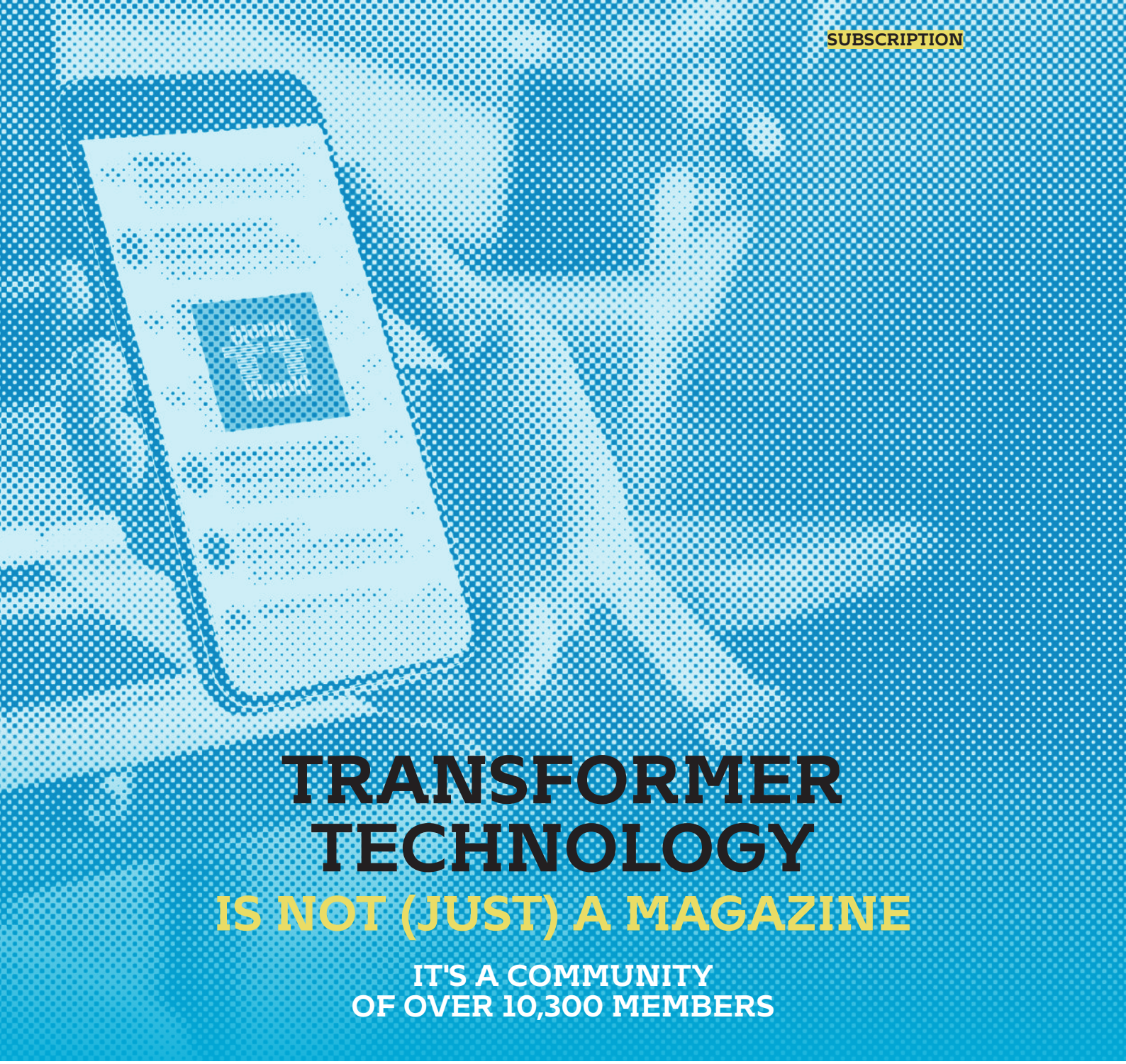

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Pierce Atwood LLP is pleased to announce that energy partner Joe Donovan has been named executive director of the Transformer Manufacturing Association of America.

TMAA is a national trade organization serving as the voice of the domestic transformer manufacturing sector on a wide range of policy and regulatory issues, and is an important informational resource to its members. TMAA's members include domestic power transformer manufacturers, related service suppliers, vendors, contractors, and utility customers.

As executive director, Joe will lead TMAA's administrative function and support the industry's leadership in pressing federal policy initiatives such as supply chain concerns, the application of the Defense Production Act, and providing a unified position before Congress, the White House, and the U.S. Departments of Energy and Commerce.

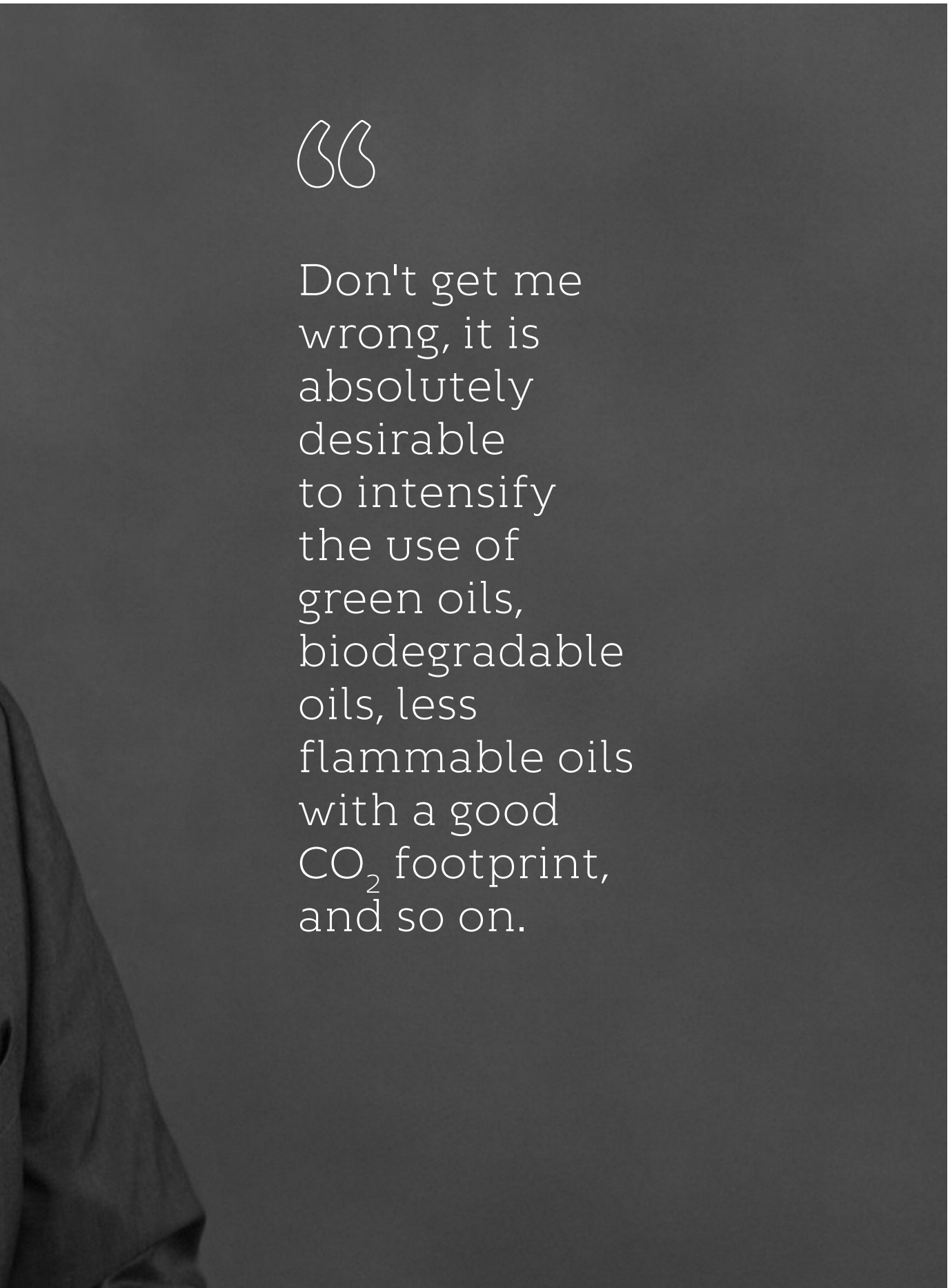
If you're interested in learning more about TMAA and its membership opportunities, please contact Joe at **jdonovan@pierceatwood.com**.

Rainer Frotscher

Senior Expert for Insulating Liquids, Gases and Tap Changers at Maschinenfabrik Reinhausen

Interview with **Rainer Frotscher**

Photo: MR



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Don't get me wrong, it is absolutely desirable to intensify the use of green oils, biodegradable oils, less flammable oils with a good CO_2 footprint, and so on.

Green Oils - The Power behind the Power

Alan Ross: I am delighted to have as a guest today, Rainer Frotscher, who is the Senior Expert for Insulating Liquids, Gases, and Tap Changers at Maschinenfabrik Reinhausen (MR). It is so good to have you.

Rainer Frotscher: It's my pleasure, thank you for inviting me.

AR How long have you been with MR?

RF Oh, about 36 years.

AR That is a long time to be a technical expert. Tell me a little bit about your background. Did you have a degree in chemistry or chemical engineering?

Unlike in the rest of the world, in the US, most of the transformers are sealed but when you want to use natural esters, then you must rethink how to seal the tap changer as well.

RF No, I'm an electrical engineer, and I studied high-voltage engineering in Munich. After my studies, I came here to Reinhausen and I found a very good environment to develop tap changers and to do calculations and really did deep dives into numerical field calculations, project studies, and on how tap changers interact with insulating liquids. And then over the years, this developed into my favorite subject, and I just sort of picked up the chemical knowledge on the go, as it were.

AR There's a gentleman named Dan Martin whom you worked with and he said to me *Rainer knows absolutely everything to know about tap changers*. So, you're going to be our tap changer expert. I'm going to add even more to your title. I would like to hear your insights on the changes happening in the industry with the addition of a lot of synthetic esters, natural esters, and even changes in mineral oils and the fact that tap changers need to be looked at specifically when it comes to fluids. Could you please talk about what the current situation is as it relates to oils and fluids and these new products?

RF Yes, that is true. The current situation is that many new liquids are entering the markets. There are new synthetic esters and a bunch of new natural esters, plus the further developed so-called mineral oils which are GTL oils and oils made from renewable hydrocarbons. They are all entering the market simultaneously, and all are a little bit different, and they are also very local. Every country is trying to develop its own liquids for reasons I don't know. But it creates a challenge for us because we have to approve them all. Don't get me wrong, it is absolutely desirable to intensify the use of green oils, biodegradable oils, less flammable oils with a good CO_2 footprint, and so on. But all transformer, bushing, and accessories manufacturers have to invest a lot of time and effort to qualify all these new liquids. And this leads to the situation that each equipment manufacturer designs its own test procedure because the current standards do not provide them. These standards do not cover all liquid properties which determine the performance of the equipment. They only determine some properties of the liquid itself, but not how it interacts with the equipment.

Photo: MR

AR I remember reading something you said about this. I believe you said that part of the problem is the standards for the alternative liquids were created based on transformer mineral oil standards. So, it's not like they were specifically created. The standards were created for something that's been used in transformers for years. What then is the difference when you're using alternative fluids and you're developing new standards for them?

RF As I said, there is much research going on, both in the industry and in academia. And these researches have revealed that alternative liquids, particularly esters, show significantly different properties. For example, when it comes to the dielectric properties, like the streamer breakdown properties. They are significantly different. And in combination with the complex insulating arrangements which you find in a transformer or a tap changer, this leads to a different dielectric strength. Other very important factors for tap changers are the viscosity range, lubrication, oxidation stability, and so on which are all different. We must take all that into account. Another example is the sealing of transformers. Unlike in the rest of the world, in the US, most of the transformers are sealed but when you want to use natural esters, then you must rethink how to seal the tap changer as well.

AR I would like to go back to lubrication for a moment. Because we don't think of that in transformers. I don't think it needs lubrication, but it's an important part of what the

liquid does. It has to have lubrication qualities. Could you elaborate a little bit on the lubrication requirements for these alternatives?

RF All types of tap changers were originally designed for mineral oil. This is what all mechanisms have been optimized to. But now we have these biobased hydrocarbons or GTL oils which can be very low-viscosity liquids. And viscosity is connected to the lubricating behavior. Not directly, but it has a certain influence. And when the viscosity is too low, then the lubricating properties can be insufficient which leads to functional problems, as it affects the switching sequence of the tap changer.

AR But there are also other complex situations that you've got to think about, the sludge and soot and arc quenching and all of the other things. Talk a little bit about the different application requirements of the alternative fluids. How do we prevent the buildup of sludge at the bottom of the tap changers?

RF It actually gets even worse if you run these old arc-breaking tap changers with ester liquids. The viscosity is somewhat higher, which means that the arc is not cooled as directly and efficiently as it is in mineral oil. So, the arcing time is somewhat longer, which produces more sludge and also may produce some unwanted gasses. If you do

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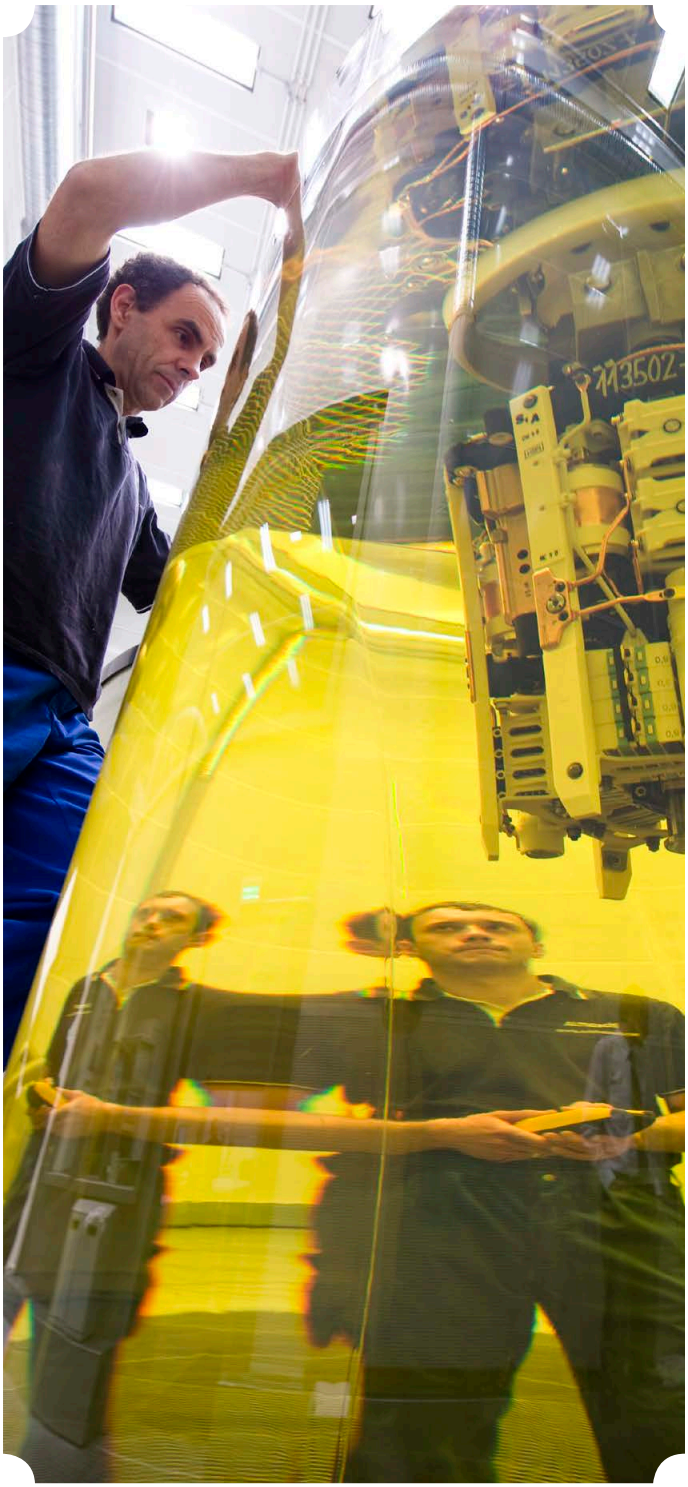

some maintenance on these tap changers, you should provide a good ventilation system so that some possibly toxic gases can come out. So, this is what happens when you have a pyrolytic degradation of ester liquids and this is the reason why Reinhausen doesn't approve ester liquids in combination with arc-breaking tap changers, only with vacuum-type tap changers. There, esters work just fine, without sludge or toxic gas byproducts.

AR I would like to talk about different segments because I honestly don't believe most of the market understands the issues. You said you're not quite sure why each country is producing its own, different fluids. It's called politics, okay? Each country has its own thing. Somebody tells the politicians, who then tell the regulators, who tell the manufacturers, that's how it goes. But what can liquid manufacturers, the people that make these alternative fluids, do?

Viscosity is connected to the lubricating behavior, and when the viscosity is too low, then the lubricating properties can be insufficient which leads to functional problems, as it affects the switching sequence of the tap changer.

RF They should take into account the elaborated requirements. It is not only about electrical insulation and cooling. There are also additional properties of the tap changers like an adequate viscosity range and compatibility with all existing materials and designs.

AR An alternative fluid manufacturer who was out trying to sell his product to, either the specifiers at the utility or whoever is buying the transformer needs to ask questions about applications. How is this going to be used? What kind of tap changers are going to be used? And then that way they can become consultants if you will. That way they could learn how to make the fluid that fits the customer's needs best. But they're not going to do that. What they're going to do is make a problem.

RF Yes, they simply don't seem to be aware of all these issues in detail.

AR Exactly. And that's why we're doing this, to make them aware. Reinhausen makes load tap changers, and you are the global leader of load tap changers in the marketplace and have been for a long time. So, you're the equipment manufacturer. Could you talk a little bit about what the equipment manufacturers ought to do to address this problem?

RF From our meetings with transformer manufacturers, we have learned that they all have their own test setups for their insulating arrangements like paper-wrapped windings, for example. They have established test setups and they test with AC or with a lightning impulse which is quite similar to that what we do. So it would be a good idea to bring us all together to come up with simple and practical setups and methods and to develop model arrangements that are applicable in practice and that represent real insulating arrangements. The standards we have now for dielectric strength, and for breakdown voltage, are not sufficient because they only allow

an estimate of the dielectric strength of the liquid, but not of the complete insulating arrangement.

The standards we have now for dielectric strength, and for breakdown voltage, are not sufficient because they only allow an estimate of the dielectric strength of the liquid, but not of the complete insulating arrangement.

AR At the end of the day, the end user, the customer, says, *Hey, we need a transformer or a series of transformers and we have to specify them*. What do you say to the end users in their specification projects? There is an electrical engineer sitting in a room with no windows and he's told to develop the specs and he's disconnected from things going on on-site. What can you tell him or her about what they need to do?

RF It's not so easy but perhaps he could encourage the liquid manufacturer to develop environmentally friendly liquids with properties that are not too far away from what we know from classic mineral oils.

AR And that will force the liquid manufacturers to really look into what changes in viscosity they need to make. Because I think, as you have stated, they can do that, but they just have to have a standard to go by. And without well-developed industry standards, they're going to have to go by the specification

Photo: MR

standard that the end user uses. Talk about what you are talking to the industry now. Your fellows in the IEEE transformer committee and your fellows at CIGRE and IEC talk about what they can do in order to address this problem. Because it's going to create greater problems down the road sooner rather than later and people are going to go *It's because of the fluid.*

RF The industry should do, what I'm currently doing. I'm working on the IEEE C57.166 which is the combined liquid guide that combines all the previous liquid guides for mineral oil, for synthetic and natural esters, and for high molecular weight hydrocarbons. I had an annex inserted into this guide which puts the finger on these special issues, special requirements, that tap changes have. I think that CIGRE could also set up a working group, for example, where manufacturers, be it for transformers or other equipment, come together to propose and agree on test methods that allow an estimate of the performance of liquids.

AR Well, this has been a delight. Rainer, thank you for joining us, this has been very informative. We will do some follow-up interviews on this because I'd like to find out more, and I'd like to use this to help the industry come together. Thank you for sharing with us the problem and the solution for equipment manufacturers, liquid manufacturers, for end users, and for the industry.

RF Thank you, Alan, for the opportunity.

Getting the Most out of Key Gas Monitoring

by **Chris Rutledge**

As maintenance practices for utilities are quickly shifting from cyclic to a more condition-based approach, it has become a customary practice to install online monitoring for most high-value assets. Much of this monitoring has focused on dissolved gas analysis for power transformers. The formation of hydrogen and hot metal gases is typically the leading indicator of excessive thermal conditions developing within the transformer. This can result in solid insulation degradation, causing the unit's premature failure. While there are several approaches to applying this type of monitoring, ranging from complex multi-gas systems to key gas monitoring, there must be a good understanding of the data being collected and how that data can be used to best determine the overall health of a particular transformer. When key gas monitoring is considered, it requires a good understanding of several factors to establish a successful monitoring program. This would include the types of conditions associated with various levels of hydrogen generation, where alarm points need to be set to best detect these conditions, and how to utilize offline tests in conjunction with key gas monitoring to provide the best assessment of transformer health.

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Chris Rutledge is currently an Applications Engineer at Dynamic Ratings, Inc. He joined the Dynamic Ratings team in July 2019. Prior to his present position, he served as Substation Asset Manager and chairman of the Substation Safety Committee at Memphis, Light, Gas and Water. He has 27 years of experience in the utility industry, primarily focused on the installation, service and maintenance of both substation and distribution equipment. He has done extensive research and published multiple papers concerning the interpretation of dissolved gas analysis testing. Chris is dedicated to assisting customers in finding creative cost-effective solutions for improving safety and reliability across their entire electrical system.

Introduction

While some form of dissolved gas monitoring has become a standard practice for most utilities, there is still a strong reliance on the data collected from manual samples. This continuance of manual testing procedures, even in cases where there are multi-gas monitors in place, should raise the question of what purpose in the overall maintenance plan these monitors serve. To best answer this question, there are several factors to be considered, such as the type of monitoring being installed, as there is a much higher level of analytics that can be performed using the data collected from a multi-gas monitor compared to that of key gas monitoring. How is the transformer being operated? This question is critical when determining the type of monitoring being installed as transformers, which are heavily loaded, tend to operate at thermal conditions which can cause a considerable amount of hydrogen generation and make it difficult to assess the health of the transformer on hydrogen values alone. Finally, how frequently is the offline DGA testing being performed? Typically, if samples are being collected on an annual basis, this can provide enough data to detect many of the common root cause failures, as transformers tend to show deterioration over a period of several years before failure occurs. Monitoring is then responsible for detecting conditions that can occur suddenly between sample periods. These would include things such as partial discharge, in-tank arcing or exposure to high through-fault values. Since hydrogen is typically the leading indicator of these conditions having occurred, key gas monitoring should provide a reasonably high level of confidence that there has not been a sudden change in transformer condition since the last oil sample was collected. Therefore, this article will examine the use of key gas monitoring in conjunction with trending data from manual samples as a means of maintaining optimal transformer reliability.

Hydrogen Generation

Hydrogen monitoring represents one of the earliest and most frequently used types of online transformer monitoring. This is due to its relatively low cost, ease of installation and the association of hydrogen as being an indicator of many of the common faults which occur in transformers. To better understand this association, an examination of the conditions under which hydrogen is produced and empirical data from case studies will be displayed.

Hydrogen in transformers is produced due to a breakdown of the hydrocarbon chains which form mineral oil. This process starts when the thermal, condition within the transformer exceeds 150°C. At this point, we would begin to see hydrogen and methane molecules as a byproduct of the degradation of the temperatures increase, these methane molecules will be replaced by ethane at around 250°C, ethylene at around 350°C and finally acetylene at 1000°C. However, despite these changes in the production of other hydrocarbon gasses, hydrogen production remains constant through all these thermal ranges. It is this consistent formation despite the thermal condition that makes hydrogen an ideal key marker for single gas monitoring. Taking that into consideration, there are several adverse conditions that can occur within a transformer of which hydrogen is a leading indicator.

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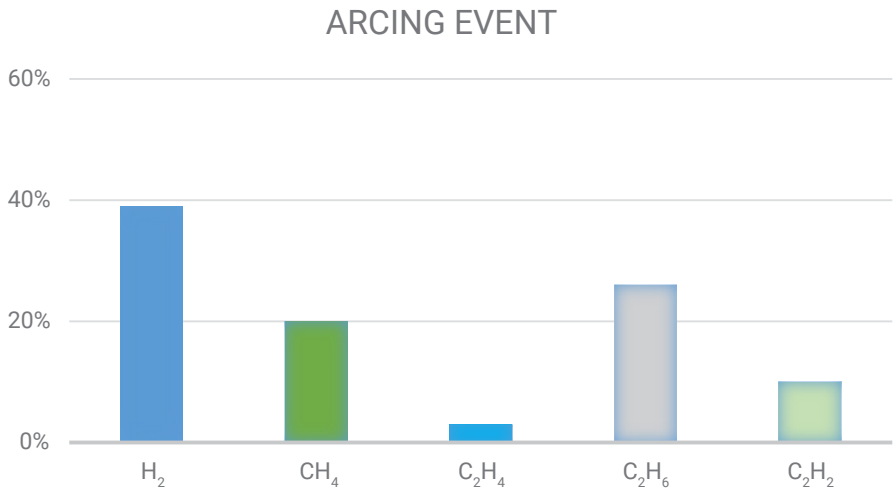

Hydrogen in transformers is produced due to a breakdown of the hydrocarbon chains which form mineral oil.

Event 1

is from a transformer that experienced an internal arc while in service.

The DGA results from this event exhibit a signature example of arcing occurring within the transformer. The key indicator of this arc being the levels of hydrogen present are roughly two times greater than that of acetylene. While the key gas monitor alone would not allow this analysis to be performed, the levels of hydrogen produced would be sufficient to raise an alarm that the event had occurred. Typically, these types of events tend to occur suddenly and result in relaying tripping the unit out of service at which time a DGA sample could be collected, and a full analysis performed. Another factor that needs to be considered is that saturation of the gasses into the oil does not occur instantaneously, and in some cases may take as much as 24 hours before an accurate assessment of the event can be made. So, when these types of events occur, there would be little advantage in having a multi-gas monitor in place, other than the ability to perform an analysis of the event remotely once equilibrium of the gasses had occurred.

In instances of partial discharge occurring within the transformer, hydrogen is the key indicator. Because partial discharge typically starts as a low-energy event, thermal conditions are lower than those associated with other types of incipient faults.

Event 2
DGA Test Results

In Event 2, hydrogen is the key indicator of PD occurrence followed by the production of methane and low levels of ethane. However, it should be noted that as this condition evolves in severity, we start to see increased production of ethane and ethylene, which is indicative of higher thermal conditions developing at the site of the defect. Again, this level of analytics is not possible with key gas monitoring alone, however key gas monitoring would have raised an alarm to provide notification that the PD event is present and allow for preventative action to be taken.

Setting Alarm Points

Many of the conditions associated with sudden failure, which may develop rapidly between manual sampling intervals, can successfully be detected in their initial stages using key gas monitoring. However, another critical point to consider is at what level alarm points should be set at for the earliest notification of these critical conditions. While setting alarm points based on a total ppm value can prove to be useful in detecting abnormal conditions, there are several factors to be considered when establishing these limits. The first thing to be established when setting alarm points is the historical data for the transformer on which the monitor is installed. While IEEE guidelines provide a useful starting point, the user must review historical data for the transformer to determine what is considered normal operational levels. For many transformers, this will be well within the guidelines recommended tables, but in other cases normal operation may range in the 100 or 200 ppm range. By examining the transformer's historical DGA data, alarm points can be established in a manner that provides notification when gas levels have deviated outside of that transformer's normal operating levels. This approach will help eliminate instances of false alarms occurring. Another approach to consider is alarming based on a rate of change. This can be done in unison with the total ppm values but provides much earlier notification that something has changed in the way the transformer is performing. These rate of change alarms can be based on daily, weekly, or monthly rates of change. The reason these alarms are preferred is that the sudden generation of hydrogen can always be associated with an active event occurring within the transformer and will provide an alarm even if the levels of hydrogen generated do not exceed a total ppm value. This is important because of the volatile nature of hydrogen when in a dissolved state. Hydrogen is the least soluble of all the hot metal gasses and tends to diffuse quickly across the oil gas partition. This in conjunction with hydrogen's nonhomogeneous distribution in the oil can lead to a cumulative ppm value representative of actual hydrogen generation difficult to achieve at the monitor's static measuring point. These physical attributes of hydrogen, combined with any possible leaks which may be present in the transformer's tank, can greatly affect the levels of hydrogen saturated in oil, causing total ppm values to appear much lower due to the loss of hydrogen to the atmosphere. In these instances, the rate of change alarm may be triggered based on a 25-ppm daily rate of change, whereas the total ppm value may never be exceeded due to conditions not allowing for complete saturation of hydrogen in oil.

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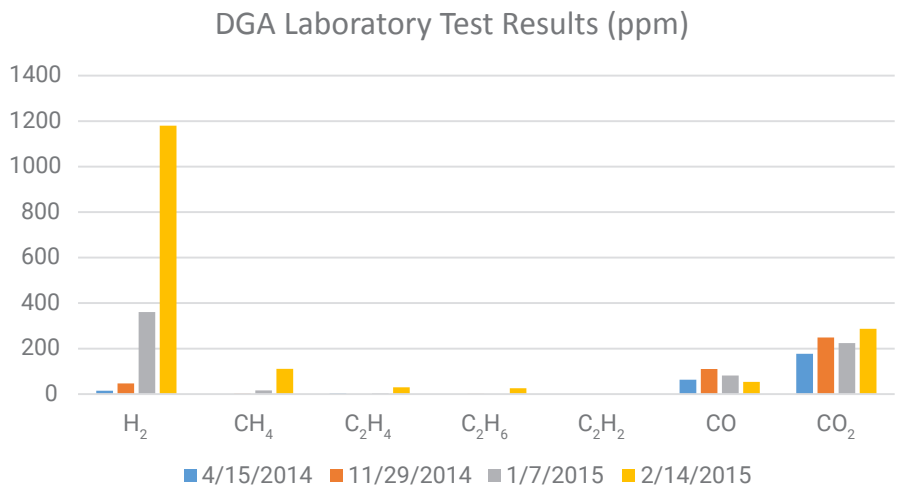

While key gas monitoring can prove effective in detecting changes in transformer condition in the incipient stages it is not comprehensive enough to forego the manual DGA testing required to optimally maintain a transformer fleet.

Developing a maintenance plan

While key gas monitoring can prove effective in detecting changes in transformer condition in the incipient stages it is not comprehensive enough to forego the manual DGA testing required to optimally maintain a transformer fleet. This requires a combination of routine sampling and electrical testing or monitoring in conjunction with key gas monitoring to provide the most reliable level of service. With manual sampling, many conditions which could lead to transformer failure can be detected, many of which would not be associated with rapid hydrogen generation. A good example of this would be moisture ingress into the transformer's tank. While this could easily be detected through manual sampling of the transformer oil, it would likely not lead to significant hydrogen production until a great deal of damage to the transformer's solid insulation system had already occurred. Also, slow-developing hot spots within the transformer may progress over time due to poor insulation or electrical connections. While this would result in some low-level hydrogen production, values may not rise quickly enough to trigger any of the alarms associated with the monitor. However, when trending values over time from manual samples, the condition is likely to become apparent through increases in ethane or ethylene values. The total ppm values of these gasses would likely be a better indicator of the condition than that of hydrogen values due to their higher solubility in oil. The maintenance plan would also need to take into consideration some of the other components which are primary causes of transformer failure. This would require online monitoring of bushings as well as OLTC compartments.

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Conclusion

Key gas monitoring can be highly effective at increasing the overall reliability of the electrical grid. This is due to its ability to rapidly provide an early warning when a transformer deviates from its normal operating conditions. Also, because of the relatively low cost of implementing key gas monitoring, it can be more widely dispersed across the entire grid than more complex monitoring systems, increasing the chances of detecting problems before they result in failure. Key gas monitoring also requires less maintenance than many multi-gas systems, allowing operating costs to be better directed. While these devices alone cannot provide the level of data needed for a comprehensive analysis of equipment condition, when used as part of an overall maintenance plan, they can be a welcome addition in the effort to improve transformer reliability.

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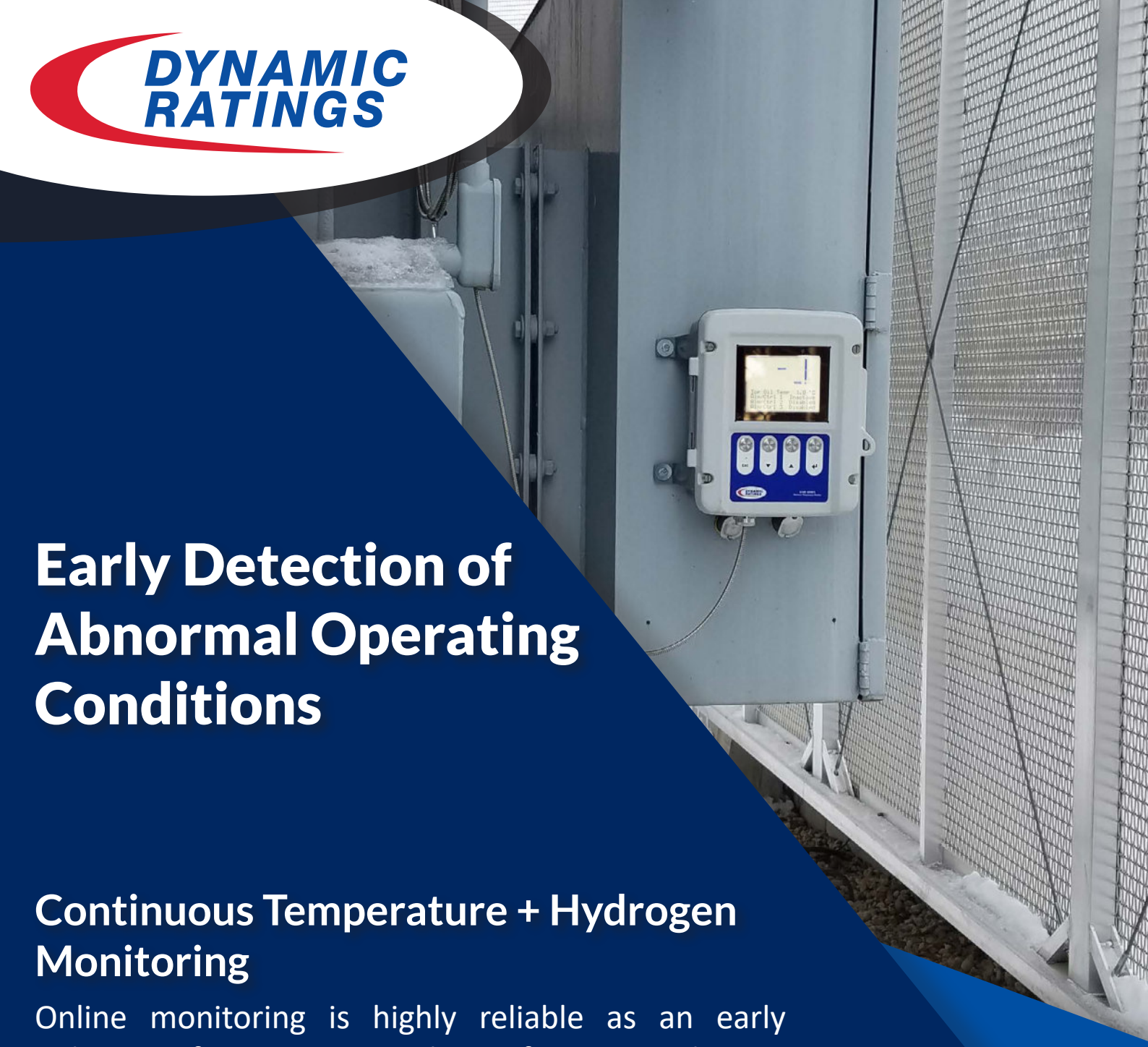
DYNAMIC RATINGS



Early Detection of Abnormal Operating Conditions

Continuous Temperature + Hydrogen Monitoring

Online monitoring is highly reliable as an early indicator of various internal transformer conditions. Dynamic Ratings' B100 Electronic Temperature Monitor + Hydrogen is an all-in-one, low-cost solution that provides remote notification of any problems detected. The B100 replaces up to five mechanical gauges and has a robust design for durability in any environment. The B100 is easy to install, configure and maintain, making your job easy. Request a quote at www.dynamicratings.com.

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Cargill®

NatureCool™ 2000
Immersion Cooling Fluid

From Plants to Processors: Cooling the Data Mining Landscape with Immersion Cooling

Immersion cooling technology has existed for decades, but within the last several years it has started to see wider adoption in commercial applications. As chip density continues to rise and the amount of data generated continues to grow, computing and data center needs will also continue to increase globally.

As a result of increasing computing power and the amount of data generated, data center power use has gone from several hundred kilowatts just 10 years ago to several hundred megawatts today, an over 1,000 times increase. This means more servers and more heat generated.

And while 35-percent of the total energy bill in an air-cooled data center is used just for cooling, the industry is seeking a more efficient solution as tighter renewable energy and greenhouse gas emission goals are established.

Companies that operate large data centers, such as Google, Microsoft, Amazon and Facebook are examples of likely adopters of immersion cooling, but anyone who operates a data center, accesses data in the cloud or at an on-site data center and cryptocurrency miners are also key end users.

Kristin Anderson is the business development manager for Cargill's global bioindustrial cooling solutions sector. She is responsible for new product development including market and industry research, channel management and marketing. Prior to Cargill, Anderson held similar roles at Honeywell, AMEC and Colder Products Company. She holds a mechanical engineering degree from the University of Minnesota.

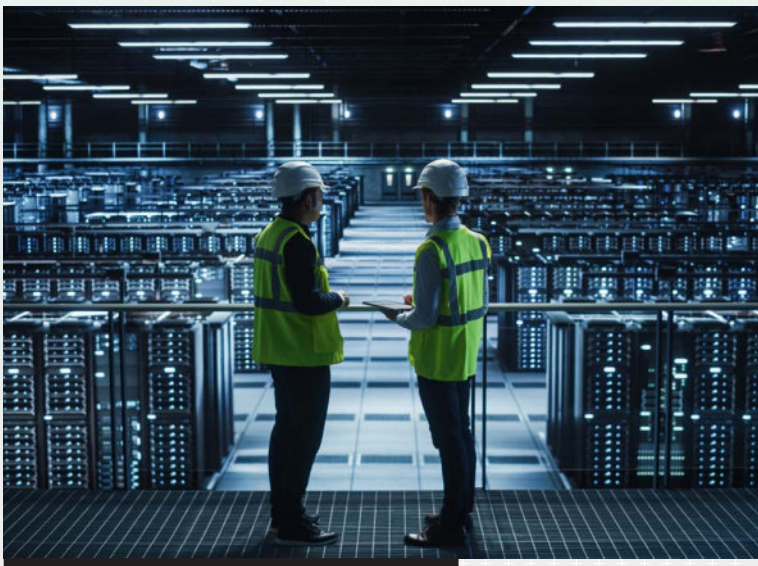
IMMERSION COOLING IS THE LATEST APPLICATION FOR PLANT-BASED TECHNOLOGY FOR CUSTOMERS LOOKING TO IMPROVE THEIR OPERATIONAL PROCESSES AND REDUCE THEIR ENVIRONMENTAL IMPACT.

AS CHIP DENSITY CONTINUES TO RISE AND THE AMOUNT OF DATA GENERATED CONTINUES TO GROW, COMPUTING AND DATA CENTER NEEDS WILL ALSO CONTINUE TO INCREASE GLOBALLY.

As the generation and use of data continues to grow exponentially, more data centers and cryptocurrency mining centers that use massive amounts of power are needed. Data centers account for nearly 3 percent of the global electricity used and over 2 percent of total greenhouse gas emissions, as much as the carbon footprint generated by the entire airline industry.

As these businesses look for ways to reduce their energy use and support corporate social responsibility goals, they are turning to immersion cooling methods to replace conventional air-cooling systems. In addition to data centers, this technology can be applied to electric vehicle charging stations and other complex electronics.

Even beyond data centers, immersion cooling applications can be found in other areas, such as electric vehicles and other computing sectors as manufactures seek a more sustainable and efficient solution.



Large data centers are turning to immersion cooling to offset massive energy demands

Photo: Shutterstock

AS A RESULT OF INCREASING COMPUTING POWER AND THE AMOUNT OF DATA GENERATED, DATA CENTER POWER USE HAS GONE FROM SEVERAL HUNDRED KILOWATTS JUST 10 YEARS AGO TO SEVERAL HUNDRED MEGAWATTS TODAY, AN OVER 1,000 TIMES INCREASE.

Computer processing equipment submerged with immersion cooling fluid

Cargill®

Understanding Immersion Cooling

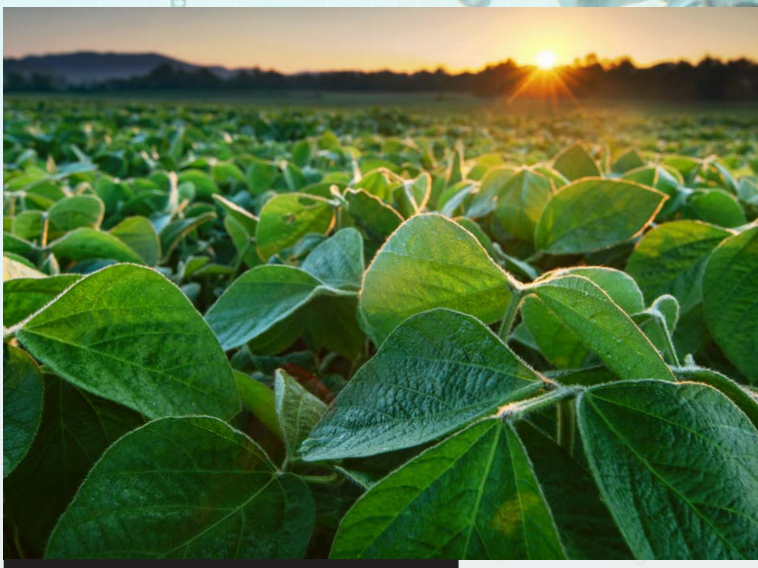
Electronic components within computing hardware are submerged in the dielectric fluid that transfers the heat from the electronics to the coolant, which then circulates to a heat exchange chamber. The cooled fluid is cycled back to the electronics in a continuous process that greatly reduces energy consumption.

This does not damage the electronics because the dielectric fluid and electronics components are designed to work together. In fact, using immersion cooling instead of air cooling typically prolongs the life of the electronic components by keeping them cooler and free from airborne contaminants like dust.

This cooling method has more than 1,000 times more cooling capacity than conventional air cooling and uses significantly less power by removing fans and large air conditioning systems, requiring up to 60-percent less energy.

Compared to conventional air cooling with HVAC systems, immersion cooling submerges servers in a bath of non-conductive liquid, allowing thermal heat generated by the computer components to be transmitted into the fluid and cooled. This method greatly reduces energy use, extends the life of the equipment, supports higher chip densities and lowers the overall operating cost.

COMPARED TO CONVENTIONAL AIR COOLING WITH HVAC SYSTEMS, IMMERSION COOLING SUBMERGES SERVERS IN A BATH OF NON-CONDUCTIVE LIQUID, WHICH REDUCES ENERGY USE, EXTENDS THE LIFE OF THE EQUIPMENT, SUPPORTS HIGHER CHIP DENSITIES AND LOWERS THE OVERALL OPERATING COST.



Plant-based innovations offer a renewable solution for common industrial applications

A Renewable Alternative

Cargill has been innovating in the bioindustrial space for many years. Given its deep agriculture and technology resources, it's working with customers around the globe to bring plant-based solutions to meet a variety of manufacturing and construction needs – from dielectric fluids to renewable asphalt, adhesives, coatings and plasticizers.

Immersion cooling is the latest application for its plant-based technology for customers looking to improve their operational processes and reduce their environmental impact.

The Minnesota-based company's newest bioindustrial product, NatureCool™ 2000, is the first plant-based dielectric immersion cooling fluid on the market for use in data centers, cryptocurrency mining and other advanced applications that allows for a more sustainable and efficient way to cool electronic systems.

The fluid, made from more than 90-percent vegetable oil, a renewable resource, along with performance-enhancing additives, allows for over 1,000 times more cooling capacity and up to 60-percent less energy usage compared to conventional air cooling. Plant-based solutions like this take the benefits of immersion cooling to another level by creating an even more sustainable method.

Cargill's NatureCool™ 2000 is the first plant-based immersion cooling fluid available

Photo: Cargill, Shutterstock

AS A RESULT OF INCREASING COMPUTING POWER AND THE AMOUNT OF DATA GENERATED, DATA CENTER POWER USE HAS GONE FROM SEVERAL HUNDRED KILOWATTS JUST 10 YEARS AGO TO SEVERAL HUNDRED MEGAWATTS TODAY, AN OVER 1,000 TIMES INCREASE.

Temps inside immersion cooling tanks are lower than conventional fan colling methods

The fluid is CO_2 neutral with a Global Warming Potential of zero, helping make applications adopting the fluid more sustainable. It has a 10-percent higher heat capacity than leading synthetic immersion cooling fluids, making it higher performing. It also provides a superior level of fire safety with a very high flash point of 325°C and unlike synthetic fluids, it doesn't self-ignite and flames out after the heat source is removed.

"Immersion cooling is the new frontier of technologies that allows for more efficient, higher performing systems that also help make the IT industry more sustainable," said Kurtis Miller, managing director of Cargill's Bioindustrial business. "In just the last 10 years, data center power usage has increased from several hundred kilowatts to several hundred megawatts, an over 1,000 times increase. As chip density continues to rise and the amount of data generated seems endless, we need to find more efficient and sustainable ways to operate these complex systems."

A Self-Contained Cooling and Heating Solution

Immersion cooling, while still a relatively new technology, is quickly becoming the preferred method for cooling power-hungry electronic equipment as data generation and online activity continues to skyrocket. What's more, immersion cooling is serving as a source for heating

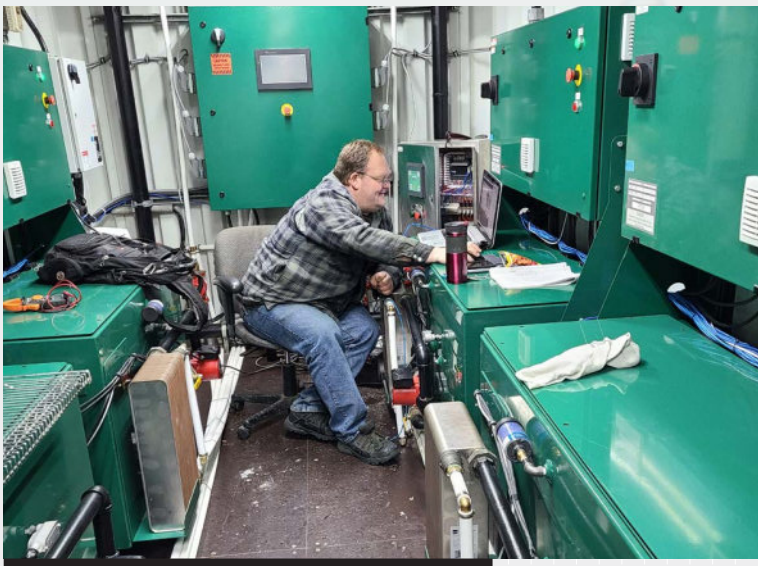
Data mining immersion cooling tanks positioned at a large ag operation in Manitoba provides an affordable, renewable heating source for their operations

buildings in colder climates without needing conventional electric or gas heat sources.

Mindful Energy Solutions, Inc., based in Manitoba, Canada, is using NatureCool™ 2000 fluid in modular data mining tanks positioned at large farming, greenhouse and industrial facilities near Winnipeg. The fluid provides a source to cool the data processing equipment and the thermal energy stored in the fluid is then upcycled as an effective and affordable heat source for warming those facilities nine months out of the year.

Mindful Energy is conducting its own crypto currency mining in these locations and is currently working with large Canadian corporations on decentralizing data mining in the same manner to reduce energy costs and power outage risks for a more efficient and renewable solution.

"We were seeing businesses with huge losses on both ends of the energy use spectrum – from inefficient cooling of processors upfront – to not having the ability to capture and reuse generated heat on the back end," said Stephane Gauthier, partner and CEO of Mindful Energy Solutions, Inc. "Now, by utilizing the heat held in the immersion cooling fluid, we're seeing some customers cover 100 percent of their annual heating cost in facilities that are over 10,000 square feet, representing huge savings while being more sustainable."



An employee with Mindful Energy Solutions, Inc. monitors tailored immersion cooling systems at an agricultural customer site

Cargill®

For more information about Cargill's NatureCool™ 2000, email Kristin Anderson at Kristin_Anderson@cargill.com or visit naturecool.com

Photo: Cargill, Shutterstock

AMORIM CORK COMPOSITES

Interview with **Marta Reinas** & **Margarida Figueiredo**

Global Technical Manager &
Global Product Manager at Amorim

Marta Reinas & Margarida Figueiredo

Photo: Amorim

> We don't damage the tree, we only use the bark.

> Cork has very good compressibility and recovery characteristics, and when we mix it with rubber, we don't lose this factor.

Photo: Amorim

Alan Ross: Hello, I'm Alan Ross, and I am the managing editor of APC Media. Today we are interviewing two members of Amorim Cork Composites. Amorim is a very unique company, in fact when I first heard about them, I thought, why are we interviewing a cork company? However, there's so much more than cork. We're going to find out today what exactly cork has to do with the power industry.

My first guest is Marta Reinas and she is an engineer and the Global Technical Manager with Amorim Cork Composites. Marta, it's lovely to have you. Could you tell us a little bit about what you do at Amorim?

Marta Reinas: Hello, Alan, it's wonderful to be here. I am a part of the Innovation Department, and I provide all the technical support to our customers and even to our commercial team. Apart from that, I'm also responsible for making all the adjustments to the formulations and also for developing new products for this area.

AR I love the innovation adjustments to the product. It's cork. How do you make adjustments to cork? We're going to talk about that. And then my other guest is Margarida Figueiredo. Margarida, thank you for being here. Could you tell us what do you do with Amorim?

Margarida Figueiredo: I work with Marta at the Innovation and Product Management Department. I'm not a Technical Manager, however, I am a Product Manager. I make the bridge between technical management and the markets. Therefore, I'm responsible for the portfolio management of our industry sectors and basically making the bridge between the market needs and to the possible applications of cork.

AR Every company is going through great changes right now specifically decarbonization. In the power industry, we have to make twice as much power and we have to reduce dependence on oil and gas. Amorim is the world's largest cork processing group, but you've gotten into other products that support that. Talk to me about the vision of the company. Where are you going as an organization?

MF I think we should start with the background and the origin of the company. Amorim Cork Composites belongs to the Corticeira Amorim. It's a family-owned company, and our origin starts back in the 70s with four generations. We started with cork, mainly with cork stoppers.

We then started to evolve as a company and began to develop different areas. We have 5 business units that belong to Corticeira Amorim which includes our raw materials division (Amorim Florestal), Amorim Cork that it´s responsible for the cork stoppers production, Amorim Cork Composite which produces composites, Amorim Cork Flooring, and Amorm Cork Insulation. Amorim Cork Composites has a presence in ten different sectors, three joint ventures, and we have a worldwide presence. When we talk about the vision of the group, specifically for the power industry, it's really important to understand that our wish is to add value to cork. As a company, we play a major role in terms of innovation and developing new products.

AR I really want to focus on what Margarida just said about adding value to cork and innovation. Marta, talk to me a little bit about how you do that in regard to the power industry. How do you add value to cork?

MR Yes, in this case, specifically, we are mixing cork with different raw materials and specifically rubbers in order to enlarge the value proposition of our materials. In mixing these two raw materials, we are able to have what we call the best of two worlds because with the introduction of rubber, we are able to have the compatibilities needed. For example, for the sealing sector, when it comes to insulating the transformers, the addition of cork allows us to have other benefits that rubber alone doesn't allow. What I mean is that, is with the introduction of cork, we are able to have a better compressibility inside of the material, meaning it has less extrusion than the rubber.

AR I want you to talk about that specific technology. Speak to our audience about why the products that you make for sealing the transformer at the top are so important and what the difference is. Because that's important to the transformer manufacturers to avoid getting moisture and air in that area.

MR Cork has very good compressibility and recovery characteristics, and when we mix it with rubber, we don't lose this factor. We add it to our materials. So compared to the traditional rubber present in the market, our cork-and-rubber materials allow us to have better compressibility and recovering solutions or properties. When we are dealing with these types of transformers, which are very large in size, sometimes they have deformations and cork, when it is compressed, absorb the

movements of the rubber, and conform to the flange's surface. Which is great for minimizing the contact or improving the contact areas and minimizing the defects that we have.

AR The cork actually acts like a sealant when you press that down, which is brilliant.

MR Yes, exactly Alan, the cork will conform and adjust perfectly to all the imperfections that you may have. It can be used with oils or as you were saying, to prevent moisture, or other substances to enter the transformer.

AR Margarida, you are talking to customers, right? Now customers are probably not used to hearing about a cork-rubber combination. It's not a normal gasketing material. How do you present that to the people who specify transformers? For instance, does your product happen at the specification level or does it happen after the transformer manufacturer gets the spec and then is just buying the material?

MF In terms of sealing, we have a long track record not from the power industry, but in the automotive industry. For more than 50 years we have been using this technique for automotive engines. Therefore, we have a lot of knowledge and background in this area. What we then decided to do is, transfer part of that knowledge into the power industry. We work with the main OEMs of the power industry, and we work with them to prescribe our materials together. So basically, we have the capability internally to help them with technical drawings for example, and we have proven throughout the composition of our materials and our reverse engineer the performance of our materials in the equipment.

AR I think that's fascinating. I'm going to come back to you, Marta, because I know you can put rubber and you can put cork. Right. But when you say it's infused, it's a different technical process of how you create it. How do you do that? I think you will be showing us a picture of that. Explain that to me because I don't understand how that happens.

MR Yes, so in our factory, we have different mixers that are able and specifically designed to mix different rubbers with cork and all the additives needed for the final product. We then mix it, and after that, we produce all blocks or cylinders that we then cut to a thickness that our customer needs.

AR Explain to me how your product helps with vibration. It does help with noise too, but to me, the biggest thing that you do is help create a stable product when it arrives. Talk about that, please.

MR When we are talking about the transportation of transformers, some of our customers have a solution that we provide together with them, with our material, for example, we may cut the cork like a donut shape to put on the pins to prevent any impact, to prevent the deformation of the transformer. This is one solution we provide to our customers. Other customers also work with some PADs to decouple the metallic parts to prevent, any damage during transportation. We also have solutions for transportation from the factories to the commissioning sites.

AR Ok so the application for your products is flat and you can add thickness, correct? Different thicknesses. These blocks can go anywhere. You can pretty much create anything out of the cork/rubber combination. Is that right?

MR Correct. Because the blocks can be cut by different means, for instance by a CNC or by water jet if needed, the thickness can be adjusted to as fine as needed so, there is no problem. And the customer can cut it according to their designs or the place of application with the traditional equipment present in this type of industry.

AR Do most people buy material and then do the cutting? Or do you sell precut, ready-to-deliver parts?

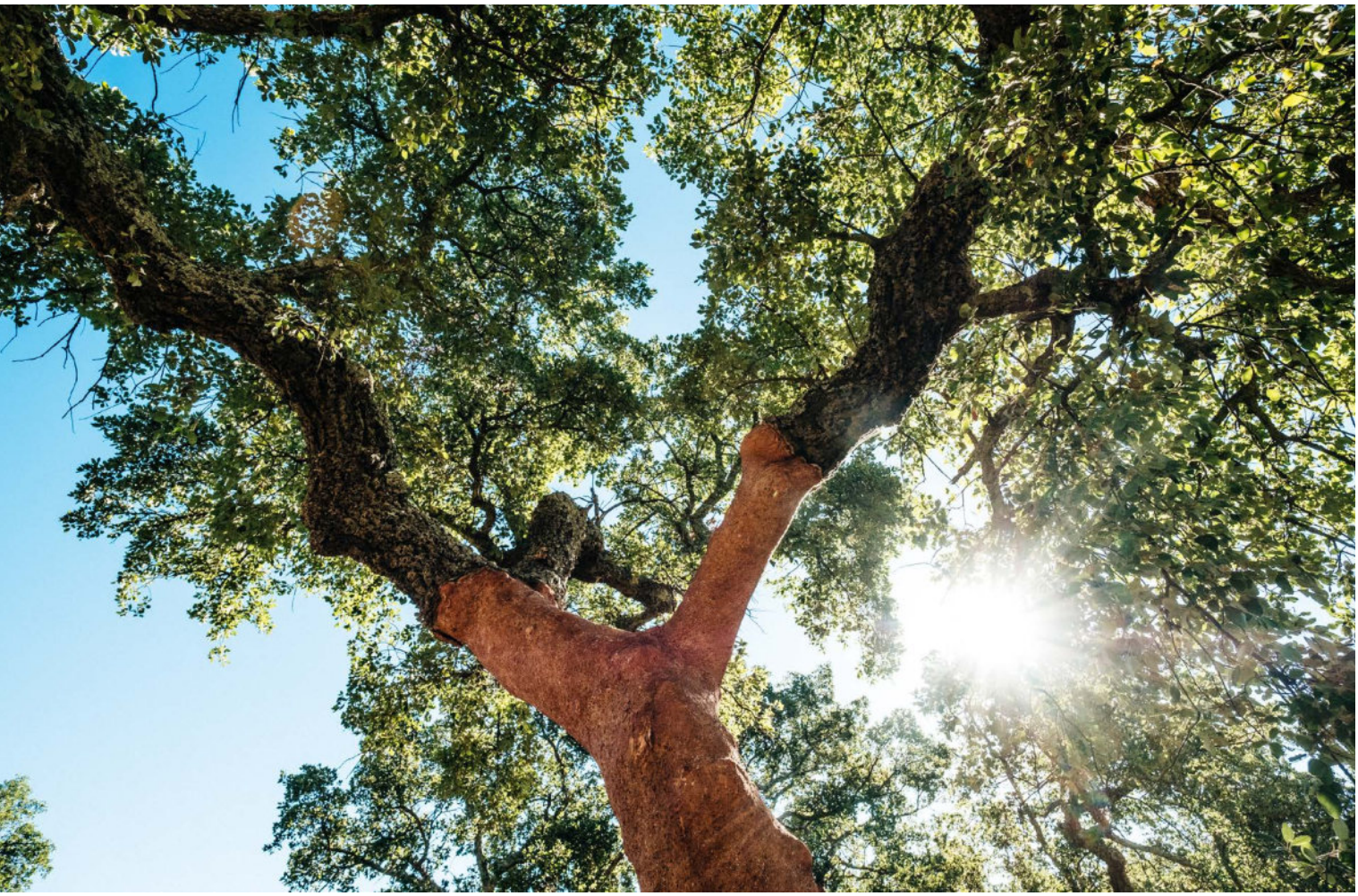
MR We work in two ways. First, our main business is to supply the materials to our customers, and then they have the technology to customize our product according to their transformer. Second, we supply it directly to the customer if needed.

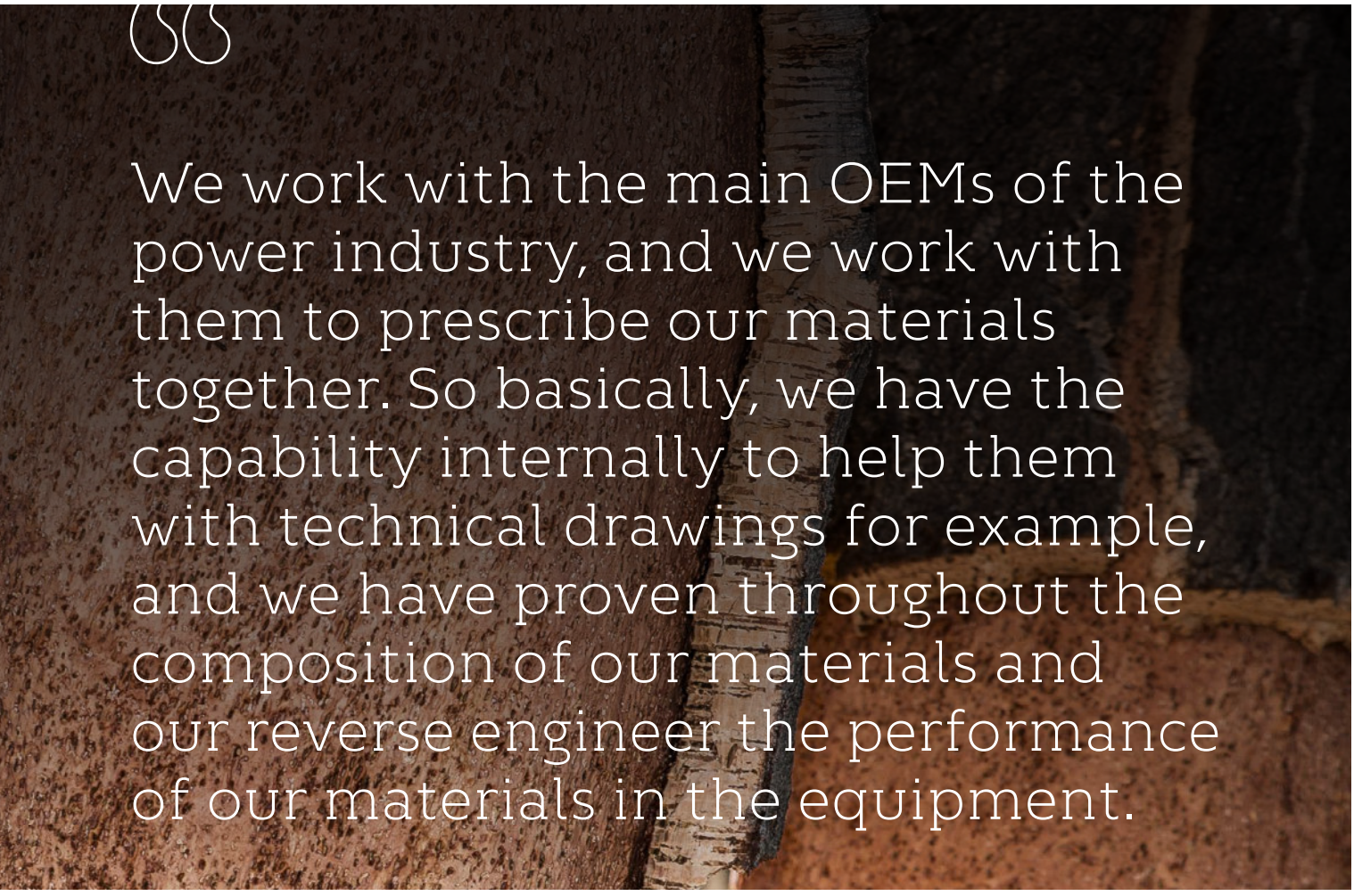
AR One of the commitments of the company is sustainability, and I love the fact that you're using cork. It's one of the most sustainable products that we can do. But where do you get the cork from?

MF The majority of cork is from the south of Portugal. And then we have some cork that we also get from the Mediterranean area. Mainly Spain, Italy, and Greece.

AR Wow you have European cork, but does it come from the cork tree? You only take the bark from the tree, right?

Photo: Amorim





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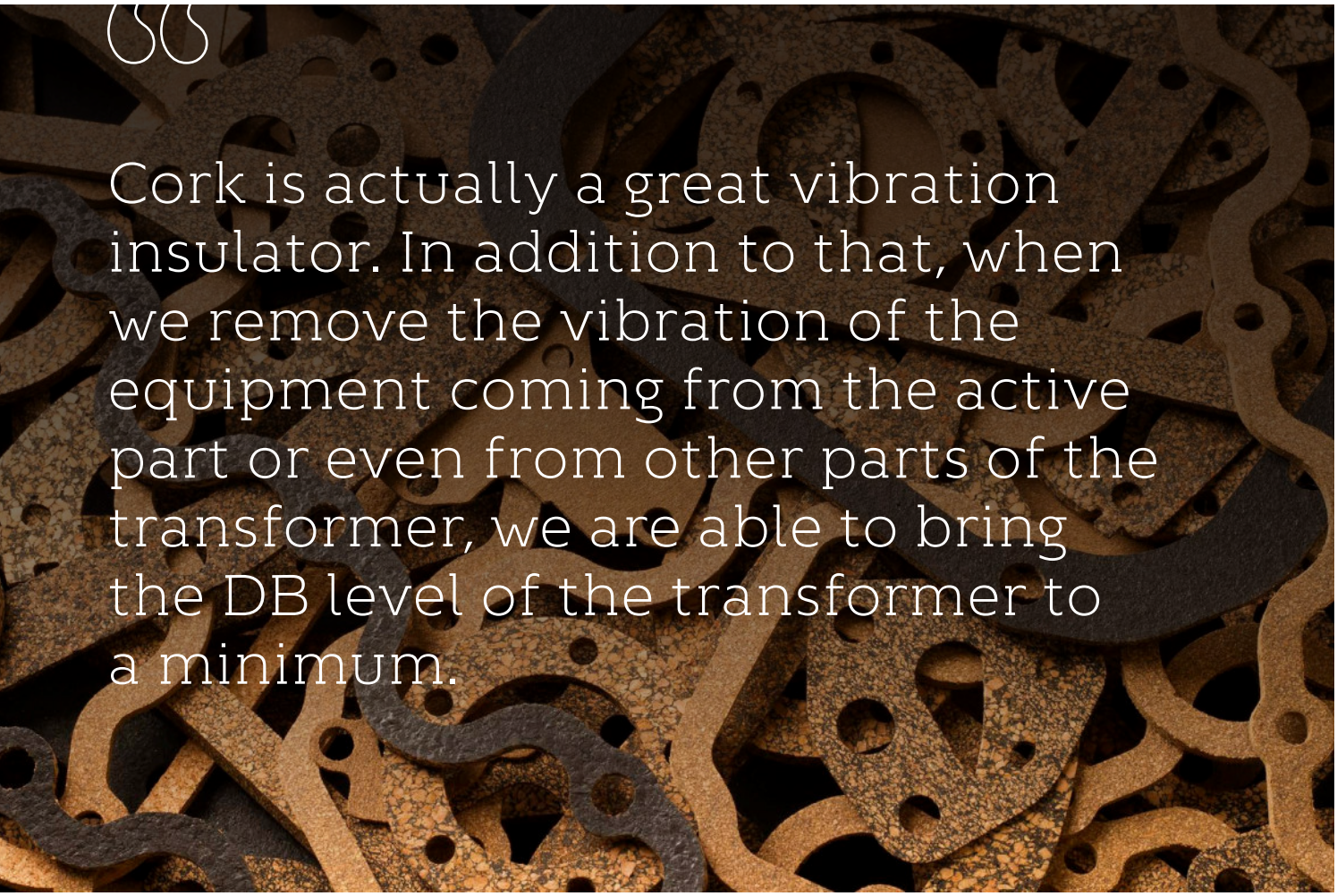
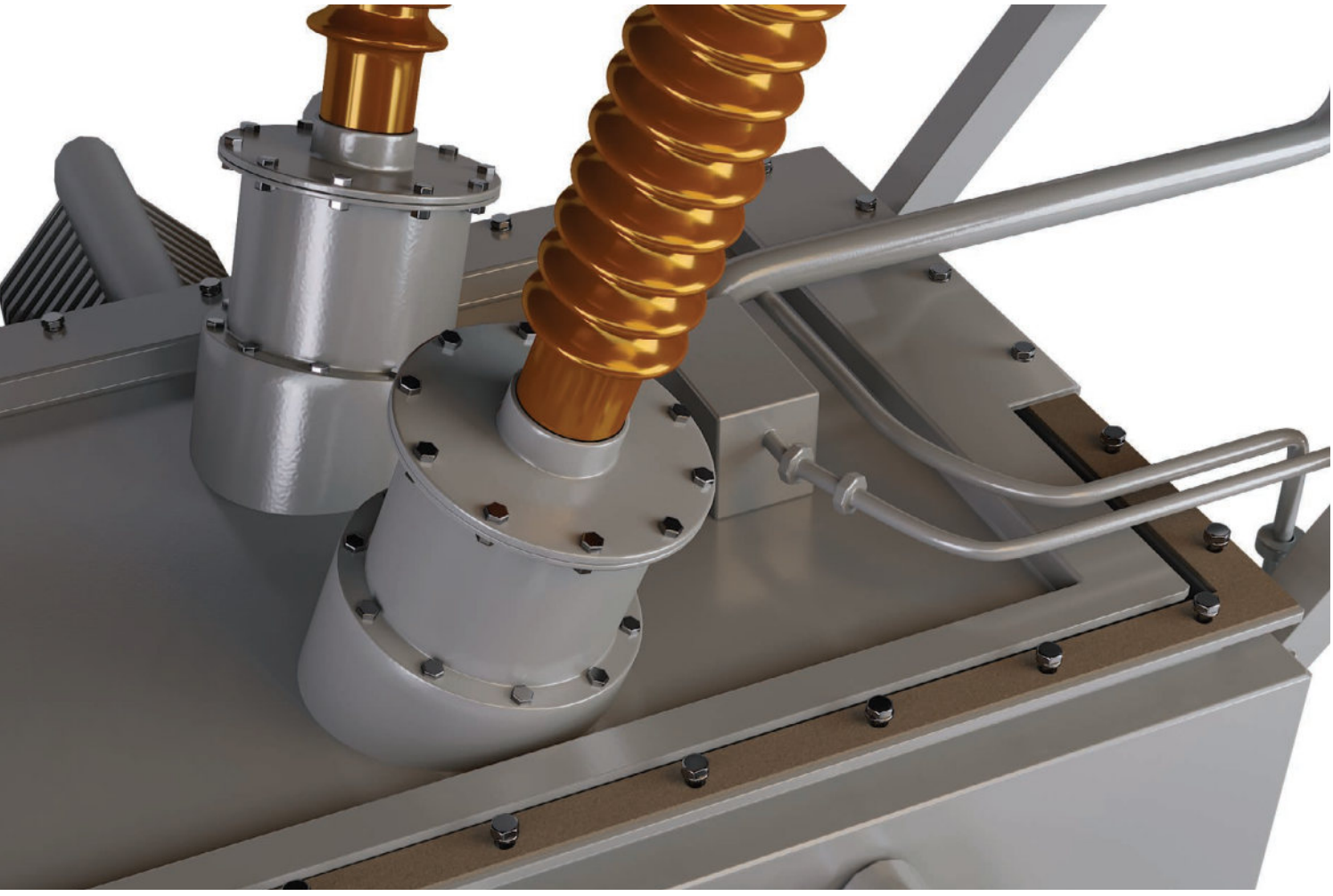


“Cork is actually a great vibration insulator. In addition to that, when we remove the vibration of the equipment coming from the active part or even from other parts of the transformer, we are able to bring the DB level of the transformer to a minimum.



MF Yes, that is correct, we only use the bark and we don't damage the tree, therefore we only take the outer bark of the tree and we harvest it. The cork tree can be harvested every nine years by peeling the outer bark and that is how we do it.

AR Marta what's next? If you can put cork with rubber and you can create this composite type material that does what it does, what do you think is next either for that material application or innovation? What are you working on?

MR We are trying to develop new materials with different characteristics in order to get to different applications or even markets that we are not present in due to high demand. We are also trying to see if we can enter into new solutions and also in new places and new types of transformers.

AR I love the fact that the company has made a commitment to sustainability and the very product is sustainable in using rubber products. Do you make your own rubber products, or are you purchasing from another supplier?

MR Yes, we supply the raw material, meaning the rubber and other additives needed for the formulation, and we mix it internally. In our factory, we have all the equipment needed to produce the materials from the mixing part to the vulcanization and afterward split it to the thickness according to the customer's needs or even finish the piece for them according to their designs and specifications.

AR Excellent. You're a totally controlled source. You make your own rubber. It's wonderful. Is there anything else that you think the customer ought to know? Anything else that you think they should know about the advantages of using core rubber?

MR Yes, we also have another solution, which is our vibration control solution. We have four of them that can be internal or external PADs material to be put inside of the tank wall, on the tank wall, and also material to decouple metallic parts. What they have in common is the minimization of the vibration of the equipment. Cork is actually a great vibration insulator. In addition to that, when we remove the vibration of the equipment coming from the active part or even from other parts of the transformer, we are able to bring the DB level of the transformer to a minimum.

AR I have a final question for you, Margarida. The problem is that transformers have been around for a long, long time and they've been made the same way for a long, long time. Now they're beginning to evolve. Talk to me as I was a customer and tell me why I should work with your company.

MF As a customer, you would want to work with Amorim because we are the world cork leader. Therefore, if you want to use cork and any of our products for this application, you won't get any other player with the presence that we have in the market. The second thing is that our brand is already consolidated in the market. Our mission and our vision for our brand is to be considered as a quality partner. In terms of quality material, you won't find any other player in the market that can deliver the quality material that we have. And in terms of distribution, we are present all over the world. Additionally, we have been in this business for more than 20 years, with the biggest OEMs. Therefore, we have a lot of knowledge and several engineering teams that are only dedicated to this sector which in turn helps our customers to provide the best solution for the power industry.

AR Well said. I've learned from working with Marta before. You've been in the industry a long, long time. You've made a commitment to the industry. Pedigree matters. You have a proven technology, you are innovating all the time. Marta, you just inspired me with the fact that cork and rubber, and innovation work together to make the transformer industry better. So, thank you for the innovation. And that's important because that's what's happening. The best companies evolve. They create products that matter!

Thank you for joining us. I enjoyed this interview with you. You're both wonderful. Thank you again.

MR &MF Thank you so much Alan.

Photo: Amorim

Diagnostics basics and laboratory data sets

by **Miroslaw Wrobel**
and **Andrzej Dabrowski**

Diagnostics to determine the status of a device have gained considerable importance in recent years for many reasons. Both technical and economic aspects play a major role. In the case of electrical energy supply devices, the focus is, among other things, on the diagnosis of the insulation system, as this largely determines its service life.

Knowledge of the operating conditions, the parameters, and their effects on the insulation system are necessary to meet the diagnostic requirements. The parameters can be obtained offline or online. This article will discuss data from offline measurements and associated diagnostic procedures and their importance.

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KNOWLEDGE OF THE OPERATING CONDITIONS, THE PARAMETERS, AND THEIR EFFECTS ON THE INSULATION SYSTEM ARE NECESSARY TO MEET THE DIAGNOSTIC REQUIREMENTS.

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Introduction

Diagnostics, as originally defined, means the ability and teaching of recognizing diseases - strictly speaking, it is the process of determining which disease or condition explains a person's symptoms and signs. In the technical field, diagnosis is associated with the term examination and the monitoring procedure with which the condition of a device or its components is determined. Sometimes including additional suggestions for measures that may be necessary. In the field of electrical power engineering, diagnosis has a much higher priority today. The desired change from previous time-based maintenance of the system to condition-based maintenance of the equipment requires better knowledge of the most important parameters of the system to be able to take appropriate and timely measures. The replacement of electrical energy supply facilities, which in the past was often caused by changes in the voltage or power level because of an increased energy requirement, is now often delayed if possible due to the increased demands on the economic efficiency of energy supply companies. Diagnostics offers a very valuable tool to evaluate the performance of existing systems and to assess the risk in terms of reliability and probability of failure. The partial redundancy of the devices is no longer maintained in the same way, so if a component fails, consequential damage occurs that can cost far more than a new one.

The technical possibilities and the costs for the collection of measurement data and their storage as well as transmission to the corresponding control centers have changed significantly in recent years so that the collection and storage of measurement values do not represent a significant economic factor, but rather the task of what the data tells us and how the issue should be solved intelligently.
The improvement of mathematical tools and the development of new evaluation and prediction methods have also led to an increase in diagnostic options, the use, and efficiency of which still must be tested in operational practice. The economic boundary conditions of the electrical energy supply will lead to an increasing load on the existing systems in the next few years, the lifespan of which is increasingly approaching the "mature" age, as shown in Figure 1 representative of the transformers of a Central European energy supplier company.

All these economic boundary conditions and increasing load have led to significant research growth in the field of diagnostics, sensors, and processing methods, and from a large number of good ideas, the best ones are proving themselves in practice now.

In the laboratory dielectric-chemical analysis according to IEC 60422 (Mineral insulating oils in electrical equipment - Supervision and maintenance guidance), the aging condition of the oil-paper insulation system is determined from key figures of the insulating oil. The breakdown voltage enables a statement to be made about the current insulating capacity of the Isolation liquid. The neutralization number (TAN – total acid number) and the interfacial tension are very sensitive indicators of the oxidation state of the insulating oil and the aging of the entire oil-paper insulating system. They are

DIAGNOSTICS OFFERS A VERY VALUABLE TOOL TO EVALUATE THE PERFORMANCE OF EXISTING SYSTEMS AND TO ASSESS THE RISK IN TERMS OF RELIABILITY AND PROBABILITY OF FAILURE.

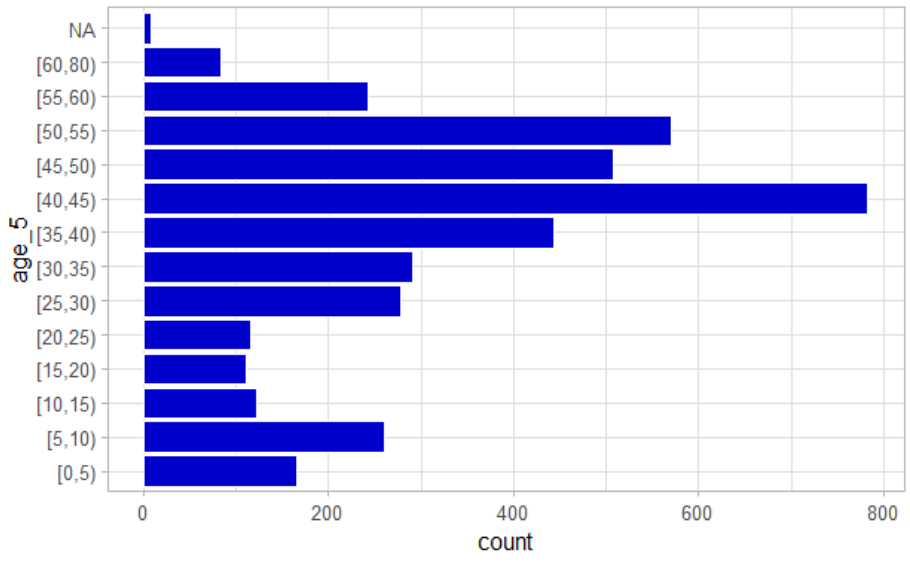
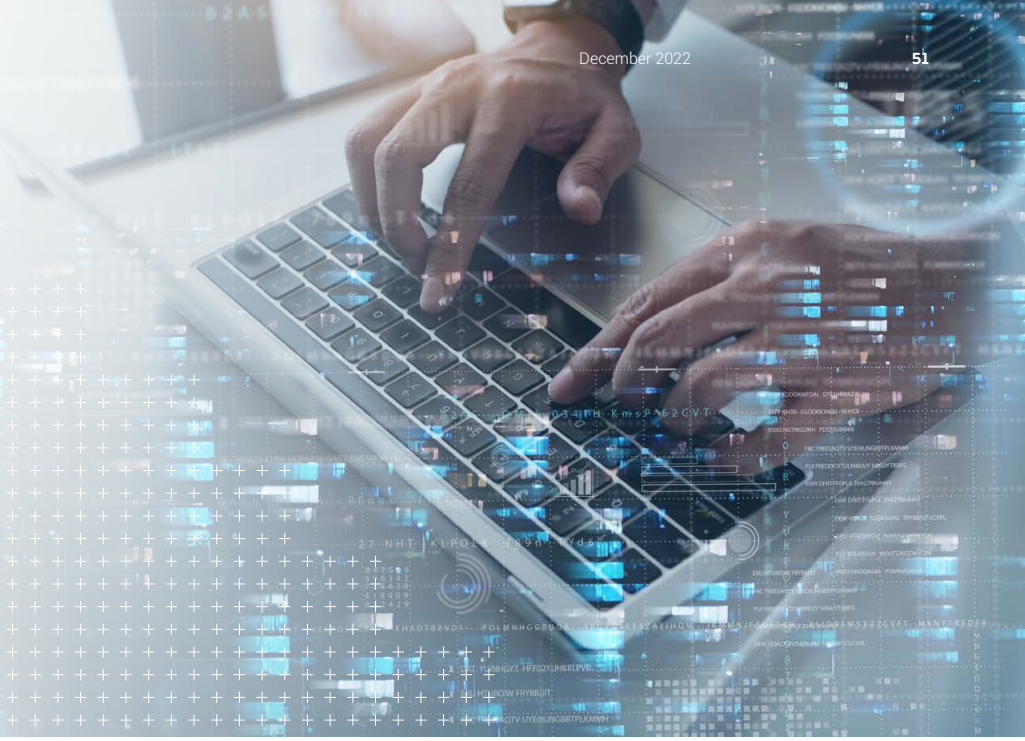


Figure 1. Average age of the transformers in the grid supply company - as an example for any middle European region

early indicators of sludge precipitation. An increased water content (Wc) drastically worsens the insulating properties of the oil and accelerates the aging of paper and pressboard.

For example, the functional diagram can show a graph of the relationship between many of the oil variables that are examined according to IEC 60422 – Figure 2. This is derived from the fact that in datasets with many variables, groups of variables often move together. One reason is that there can be more than one variable measuring the same “driving principle” that determines the behavior of the mineral oil/electric system. A multiplicity of laboratory equipment makes it possible to measure and display



dozens of system variables simultaneously. In this case, we can use this informational redundancy very well to determine the oil parameters and their "driving forces" behavior – Figure 2.

Objective of the diagnosis

The aim of the diagnosis is to offer support and expertise to meet the requirements for an economical, stable, and trouble-free electrical energy supply. Strictly speaking, it is about achieving the best possible electrical energy supply with minimal effort. What does that mean in everyday operation? This means that a prognosis for the future in terms of reliability, failure probability, and expected service life should be made from the data recorded by laboratory measurements in the past and the detailed knowledge of the properties of the devices. Such a statement must be made for a single device or for a group of devices or even an entire substation, depending on the cost of the device in question, as well as its maintenance and service. For example, because of their large number, medium-voltage equipment needs to be treated differently than high-voltage equipment, and the impact of a failure on this equipment can be very different, sometimes even very dramatic and grievous. Let's take the data from a high-voltage transformer presented in Figure 2, as an example of the task and goal of the diagnosis. Based on several thousand laboratory data sets, we were able to show that it is sufficient to measure only two of the parameters described in order to assess the BDV value - since there is a strong correlation between Wc, TAN, and BDV for mineral oil-based insulating liquids as shown in Figure 2, acid and moisture are the "driving forces" of BDV. It is known that the water content influences the properties of solid insulation materials, but Wc cannot normally be measured directly during operation, since Wc measurement needs e.g., KF-Titration.

The moisture in the solid insulating material can be determined from the moisture measurements of the liquid under known conditions, so that information about the development of the moisture in the solid insulating material can be obtained due to the established model by continuously determining the moisture in the liquid, see Figure 3 [1, 2].

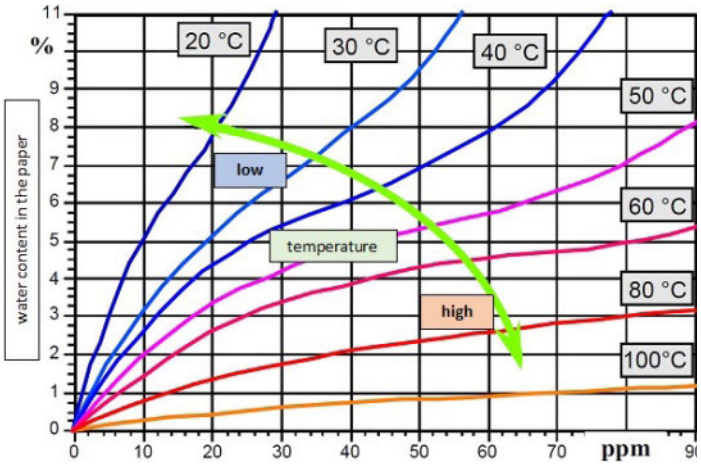


Figure 3. Moisture distribution in a paper/liquid insulation as a function of the oil temperature

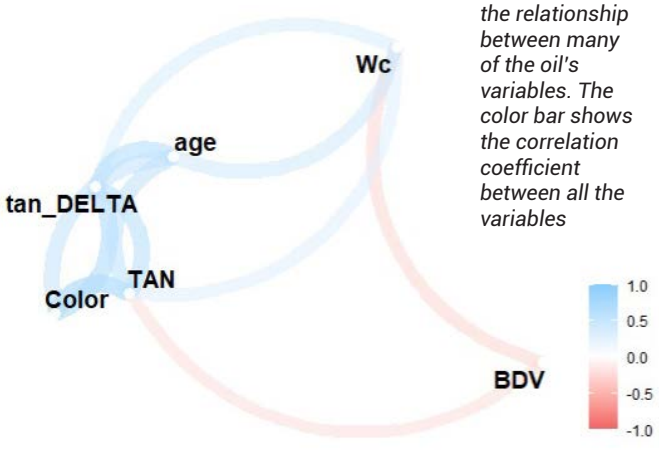


Figure 2. function chart graph of the relationship between many of the oil's variables. The color bar shows the correlation coefficient between all the variables

THE AIM OF THE DIAGNOSIS IS TO OFFER SUPPORT AND EXPERTISE TO MEET THE REQUIREMENTS FOR AN ECONOMICAL, STABLE, AND TROUBLE-FREE ELECTRICAL ENERGY SUPPLY.

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Basics & Operating Conditions

Today, paper gets its structural stability from the use of cellulose fibers made from the primary cell wall of green plants. To keep the paper stable during and after production, for example, it is treated with potassium aluminum sulfate, one of the substances commonly used in the production process here. This makes the paper weakly alkaline since the potassium aluminum sulfate lowers the paper's pH, making it acidic. This is desirable in papermaking since this additive primarily improves fiber bonding. However, if the paper is stored for a longer period of time, a lower pH value and ubiquitous moisture will lead to the destruction of the cellulose chains, as these are linked by acid-sensitive acetal bridges. This process breaks down the fiber structure of the paper. As the cellulose macromolecules break down into smaller molecular units, the paper in question loses its flexibility and tear strength. This is accelerated by the presence of water and temperature changes. This is called paper decay or "paper corrosion". It refers to the aging-related dissolution of paper, which is often triggered by the effects of acids present in the material (acid corrosion) but can also be accelerated by external influences.

From this point of view, the parameter changes recorded in the laboratory test can depend very much on the mode of operation of the device, so that evaluating the measured variables alone without taking the operational boundary conditions into account can lead to incorrect statements. Determining the moisture in the liquid and drawing conclusions about the moisture in the solid insulation material is only permissible if the entire insulation system is in equilibrium. With knowledge of the relationship between Wc & TAN (see Figure 2) as well as information on water migration between oil and paper insulation (see Figure 3), the processes observed in the older transformer population now become perfectly clear and understandable.

Unfortunately, the aging factor accelerates significantly with increasing temperature. At very high core temperatures, meaning over 90°C (190°F), the aging factor doubles with each additional 6°C (10°F). For the aging diagnostics of the paper, this statement also means that it is important to precisely know the temperature in the insulating material, especially at the points of highest temperature (core), since the aging processes experience a very strong acceleration there and lead to local destruction of the insulation and can lead to the device's failure. Due to a high electrical field strength, the occurrence of partial discharges is usually a very early warning sign for local defects and leads to an increased formation of decomposition gases

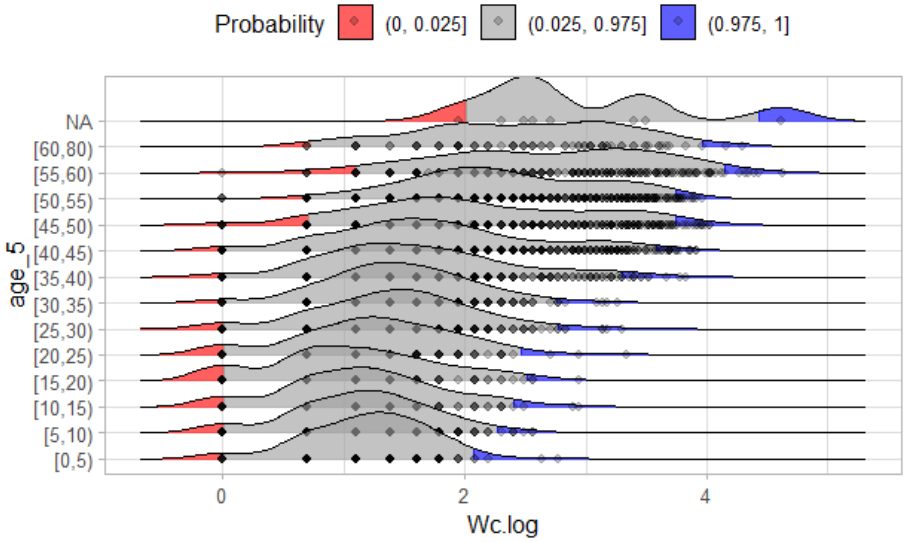

Figure 4. Water distribution in an aging transformer population

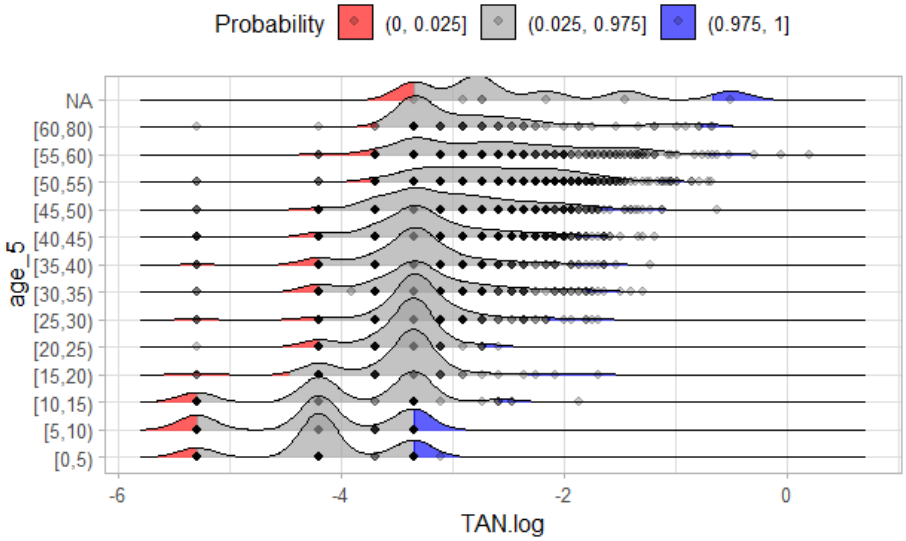

Figure 5. Acid (total acid TAN) distribution in an aging transformer population

THE MEASUREMENT OF THE DISSIPATION FACTOR TAN δ IS PRIMARILY AN ASSESSMENT OF THE LOSSES IN THE INSULATION SYSTEM AND IS THEREFORE NOT PREDOMINANTLY A DIAGNOSTIC PROCEDURE.

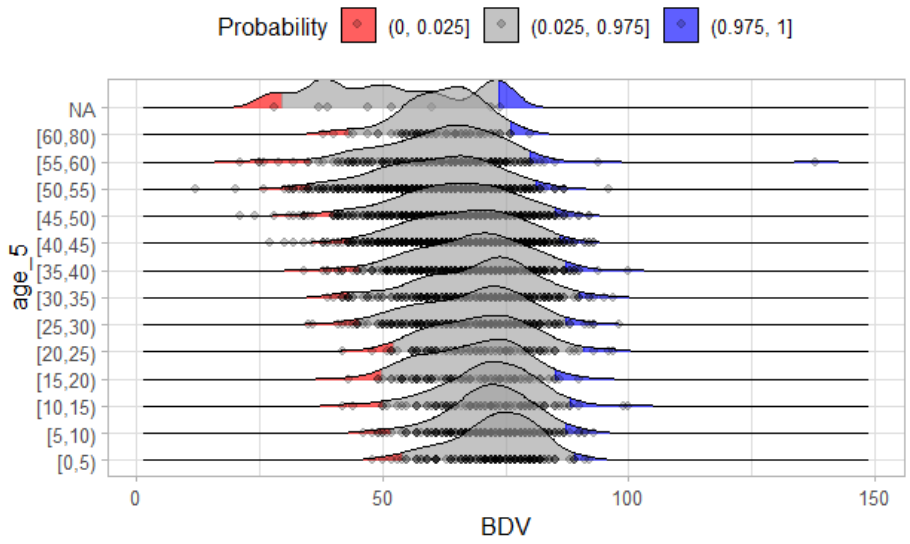

Figure 6. Breakdown Voltage distribution in an aging transformer population

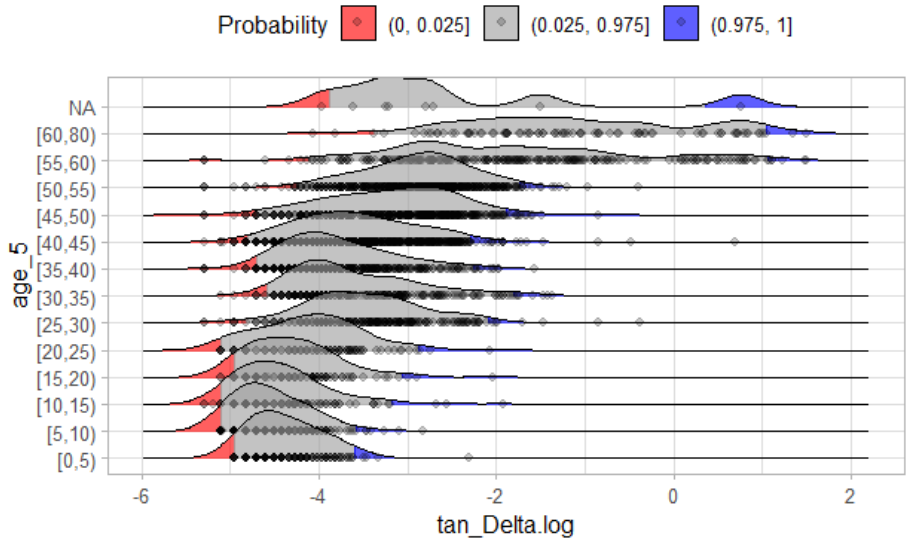

Figure 8 Change in dissipation factor tan δ in an aging transformer population

such as Hydrogen H_2. To establish a diagnosis, all of the following factors must be considered: in which insulating material these partial discharges occur, under which boundary conditions, and at which point. As mentioned above, the presence of free gases in the oil is another important factor. The DGA (Dissolved Gas Analysis) enables a diagnosis of the processes that have occurred in the insulation system, for example, partial discharges, thermal overload, or low-energy or high-energy breakdowns. Figure 7 shows that mineral oils for transformers are mixtures of many different hydrocarbon molecules and the decomposition processes for these hydrocarbons during thermal or electrical faults are complex.

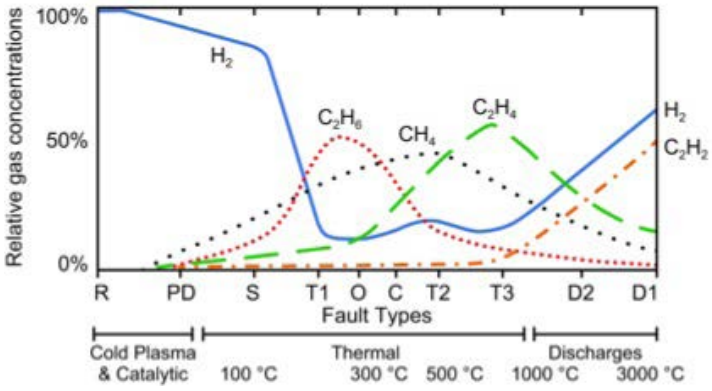

Figure 7 Relative percentage of dissolved gas concentrations in mineral oil as a function of temperature and fault type

The basic steps in gas production are the breaking of carbon-hydrogen and carbon-carbon bonds. Active hydrogen atoms and hydrocarbon fragments are formed. These free radicals can combine into gases, molecular hydrogen, methane, ethane, etc., or recombine into new, condensable molecules.

The acronyms and abbreviations used in Figure 7 mean:

- R – catalytic reactions,
- PD – partial discharges,
- S – Stray gas formation,
- T1, T2, T3 – thermal
- O – superheating of paper or mineral oil,
- C – possible carbonization of paper,
- D2 – high energy discharges,
- D1 – low energy discharges

The amount of hydrogen produced can be relatively high and temperature-insensitive for some failure types such as stray gas formation, partial discharge (PD), and catalytic failure. The formation of acetylene only becomes noticeable at temperatures close to 1000 °C. Also, the formation of methane, ethane, and ethylene each has a unique dependence on temperature. In addition to the number of gases produced by the processes, the ratio between the gas types is also important. The IEEE Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers provides a very comprehensive overview of this topic [3].

The measurement of the dissipation factor tan δ is primarily an assessment of the losses in the insulation system and is therefore not predominantly a diagnostic procedure. However, the change in the loss factor over time is an indication of aging and thus of the change in the insulation system, so some diagnostic parameters can be derived from this. It is amazing how the tan δ correlates with the changed Wc and TAN profile. Please compare Figures 4, 5, and 8. The X-axes in all of these images use the logarithmic scale to highlight and emphasize the changes over time.

Photo: Shutterstock

Conclusions

Modern measurement technology and data processing as well as data storage enable the recording of many parameters that contribute to the monitoring of an electrical system. The mathematical methods for evaluating measurement results range from simple comparisons to various statistical models and methods of artificial intelligence. From the wealth of information available, it is now a matter of selecting the most important ones and recording them systematically, as well as understanding the consequences that the data contain. It should be noted that these consequences depend very much on the respective insulation system. Is it just a single and isolated device or a group of devices or even a whole substation as recently announced? The results of this statistically supported evaluation, the importance of which is constantly increasing due to the increased use of diagnostic systems and field sensors as well as the increasing knowledge of basic research, must then be transferred to a risk and cost analysis. However, the risk analysis should also consider the following factors and the spendings: Costs for a complete replacement of the device, costs for condition-based maintenance, costs for unforeseen events and longer downtimes, and costs for consequential damage. These factors then define the costs of a diagnostic system and the possible sensors and their use. Given these conditions, a simple conclusion can be drawn. The diagnostic results to be expected regarding the assessment of the insulation systems must bring a recognizable economic benefit for the operator of these diagnostic systems. For devices with a high purchase price, which is often associated with long delivery times, and for strategically important devices, the costs for diagnosis can be higher than for devices with a lower purchase price and importance. However, the importance of a device is not only determined by its price but also very much by its place of use and the consequences associated with its failure, whereby the assessment of the importance can change very quickly here, e.g., due to changed legal framework conditions, insurance requirements or simply the possible delivery times.

Diagnostics is a decision-making factor in maintenance and asset management and can provide significantly better information about the condition of oil-insulated electrical systems with the online and real-time monitoring devices and methods available today. A sensor for oil temperature, water content Wc, breakdown voltage BDV as well as hydrogen H2 and carbon monoxide CO content can be regarded as the best and most sufficient "first line of diagnostic defense".

This applies to all systems that work with a liquid insulating agent based on mineral oil (and/or GTL based). Further studies must show whether this also applies to ester oils.

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Best practice innovative transformer oils based on Shell GTL technology

Introduction

Shell introduced in 2013, the Diala S4 range, the first and only transformer oils using unique gas-to-liquid (GTL) technology. Designed to revolutionize the reliability and lifespan of transformers, this technology has been tested and approved by OEMs and utility companies alike, and is successfully being used in thousands of power and distributions transformers globally.

The challenge

The project-team for the development next generation of transformer oil had interviewed experts at leading OEMs, Technical Institutes, and grid companies to define the requirements and criteria; good electrical behavior and thermal properties, consistent quality, long life (high grade), recyclability, miscible with traditional oils, and not to forget; maintenance tools applicable based on industry standard Oil Condition Monitoring (OCM) techniques. This article focusses on sharing best practice OCM and field experiences.

Utility companies operate large populations of 100s or 1000s of transformers, of different types, varying ages, with different operating conditions and stresses, and which can contain different transformer oils or even mixtures. OCM and database tracking, and statistical evaluation, is an integral part of a utilities maintenance activities to ensure maximum power generation and transmission performance and reliability from its assets[1], while seeking to control and reduce their total cost of ownership[2]. Electrical insulating oils have a specific and often unique list of OCM and other tests, when compared to conventional lubricants, such as DGA), DDF, inhibitor content, surface tension, etc[3], and need confirmation that new oils are miscible and compatible with other similar fluids, and can use the same suite of OCM tests and alert levels.

Insulating materials in service will age due to degradation processes such as oxidation, thermal breakdown, and hydrolysis, under moderate to high electrical stresses (depending on the transformer and conditions). OCM enables the ageing process to be tracked and interventions made before it leads to transformer electrical faults and transformer failure.

Photo: Shell

The solution

Before the Shell Diala S4 range was introduced in 2013, extensive laboratory testing was undertaken, this included miscibility and compatibility, and the resulting performance testing of mixed inhibition and unmixed, iso-paraffinic (GTL) and naphthenic hydrocarbons insulating oils, both aged and unaged, uninhibited and inhibited, and in different ratios and combinations. The data confirmed that all the tested hydrocarbon oils were fully miscible and compatible, and that mixed hydrocarbon oil systems display resultant performance properties that are an average of the type and quantity and performance of its constituent parts. The larger the proportion of GTL oil in a mixed hydrocarbon oil system, generally the greater the oxidative stability of the mixture[4],[5].

DGA testing was also run at the University of Manchester, and the Schering Institute, University of Hannover. This involved testing Shell Diala S4 ZX-I and a conventional inhibited naphthenic fluid, transformer faults were simulated covering partial discharge (high and lower energy), and thermal hot spot faults (low and higher temperature). DGA analysis of the resultant gasses was then interpreted in terms of the Duval triangle/pentagon. It was confirmed that the DGA behavior and fault diagnosis was very similar for both fluids, and that routine DGA and interpretation could be used for Shell Diala S4 ZX-I as for conventional mineral oils as expected since they are both hydrocarbon based[6],[7].

- **Case study: Switzerland**

Customer experience

A field trial to compare the DGA performance of the Shell Diala S4 ZX-I GTL based oil back-to-back with the conventional inhibited naphthenic oil, was run with a local grid company in Switzerland. BKW operates two Siemens 132 MVA transformers, which run under the same load and similar conditions, and so were ideal for this comparison testing. Samples were taken in May and June 2016, June 2017 and April 2018, and DGA performed. DGA results for Shell Diala S4 ZX-I and the inhibited naphthenic oil were very similar in trends and concentrations, confirming that DGA is suitable and reliable for both these hydrocarbon oils (see table 1).

Transformer T1	**sample Date**	**CO_2**	**CO**	**H_2**	**CH_4**	**C_2H_6**	**C_2H_4**	**C_2H_2**
	May 2016	70	22	0.3	0.3	0.5	0.5	0.2
T1 Oil: Diala S3 ZX-I (naphthenic)	June 2016	170	50	5	2	0.5	0.5	0.5
	June 2017	280	132	2.5	1	4	5	0.5
	April 2018	280	178	2.5	2	4	2	0.5
Transformer T2	**sample Date**	**CO_2**	**CO**	**H_2**	**CH_4**	**C_2H_6**	**C_2H_4**	**C_2H_2**
	May 2016	70	25	0.3	0.2	0.5	0.5	0.05
T2 Oil: Diala S4 ZX-I (GTL)	June 2016	100	60	7	1	0.5	0.5	0.5
	June 2017	260	150	2.5	2	2	6	0.25
	April 2018	275	200	2.5	2	2	0.5	0.25
Surveillance guidelines	normal	< 350	< 100	< 120	< 65	< 50	< 2	
IEEE PC57.104 D11d	warning	350-570	100-700	120-400	65-100	50-100	2-5	
	alarm	> 570	>700	> 400	> 100	> 100	>5	

Table 1.
DGA for transformer 1 filled with conventional naphthenic oil and transformer 2 filled with GTL based oil

Photo: Shutterstock

Station Transformer T8 (132 kV, 90 MVA Hawker Siddeley)				
Oil type in service	**Oil Surface Tension. Decreasing values indicate oil degradation.**	**Oil Acidity. Increasing values indicate oil degradation**	**DDF (Power factor). Increasing values indicate oil degradation**	**Dissolved gas analysis (DGA)**
Original uninhibited transformer oil, Performance change after two years in service	Halved	6 times increase	20 times increase	Normal (low)
Diala S4 ZX-I performance change after being in service	No significant change (≈ 52)	No significant change (≈ 0.01 mg KOH/gr)	No significant change (< 0.001)	Normal (low)

Table 2.
Station transformer T8, OCM data (previous uninhibited vs Shell Diala S4 ZX-I)

- **Case study: EDF Heysham 2 Power Station, UK[8]**

EDF (UK) had observed oil degradation issues in its 132 kV, 90 MVA Hawker Siddeley Station transformer T8, built around 1980. The operational temperatures of this transformer were trending higher, indicating future reducing of cooling performance. The transformer had last been filled with an uninhibited oil two years previously and was already showing signs of accelerated ageing. Following detailed technical discussions with Shell, the decision was made to replace the transformer's oil with Diala S4 ZX-I.

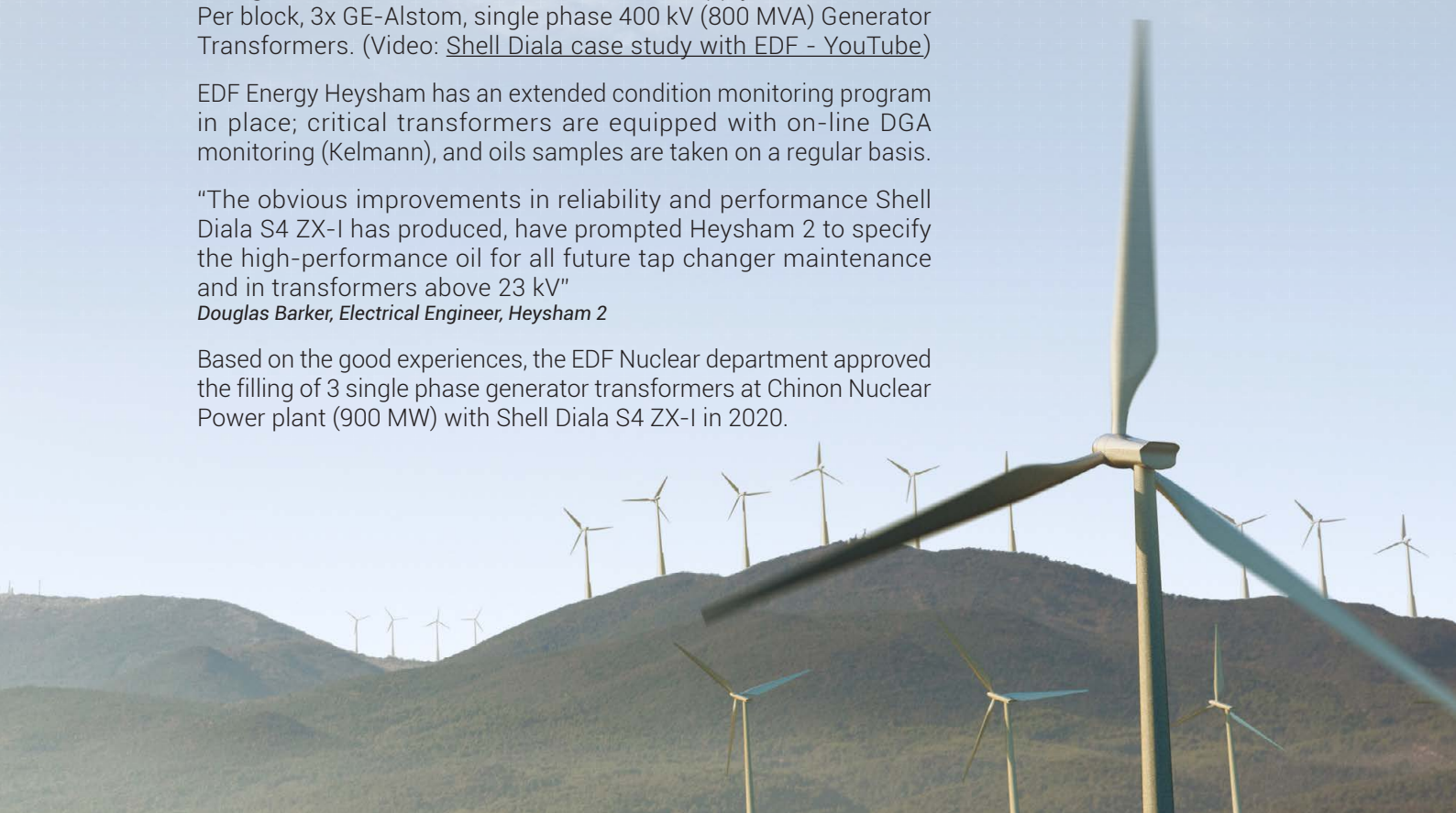
Shell Diala S4 ZX-I has now been in successful continual service in this transformer, stabile and reliable performance, and as well as the reduction in transformer operating temperature, the rate of oil ageing has also declined as shown in table 2.

Based on the good experiences with the Hawker Siddeley Station transformer, EDF (UK) decided to select Shell Diala S4 ZX-I for their new generator transformers, scheduled to supply in 2014 - 2016. Per block, 3x GE-Alstom, single phase 400 kV (800 MVA) Generator Transformers. (Video: Shell Diala case study with EDF - YouTube)

EDF Energy Heysham has an extended condition monitoring program in place; critical transformers are equipped with on-line DGA monitoring (Kelmann), and oils samples are taken on a regular basis.

"The obvious improvements in reliability and performance Shell Diala S4 ZX-I has produced, have prompted Heysham 2 to specify the high-performance oil for all future tap changer maintenance and in transformers above 23 kV"
Douglas Barker, Electrical Engineer, Heysham 2

Based on the good experiences, the EDF Nuclear department approved the filling of 3 single phase generator transformers at Chinon Nuclear Power plant (900 MW) with Shell Diala S4 ZX-I in 2020.



OEM experiences and acceptance

During the pre-launch phase, Shell technical experts have been in contact with leading OEMs, and get input on their nowadays and future requirements, and confirmation on market trends. Multi test programs have been agreed upon with OEMs (Siemens, HE (ABB), GE, etc.) and Universities [1],[7] to confirm the typical performance test data sets. These collaborations supported a smooth market acceptance of the GTL based Shell Diala S4 ZX-I.

Country	Transformer type	notes/comments
Nigeria	Power Transformers	340 KV
Vietnam	Power Transformers	220 KV
India	Power Transformers	1200 KV
Ethiopia	Power Transformers	500 KV
Kenya	Power Transformers	220 KV
Germany	Power /Distributions	220 KV and below
China	Reactors	500 KV
Malaysia	Power/Distributions	275 KV / 340 MVA
Heilongjiang province, China	HVAC, reactor	500 KV / 50000 kvar
Netherlands	Power Transformers	380 KV
UAE	Power transformers	500 KV / 882 MVA
Germany	Power transformers	400 KV
Saudi-Arabia	GSU (Generator Set-up)	400 KV / 864 MVA
Germany / Belgium	HVDC link project	380 KV
Netherlands / Denmark	HVDC link project	320 KV
Belgium	Power transformers	380 KV
UK / France	HVDC link project	320 KV
UK	HVDC link project	400 KV
Germany	Power transformers	380 / 110 KV
France	Power transformers	235 KV / 660 MVA
Italy / France	HVDC link project	400 KV

Table 3.
compact overview with reference projects

Photo: Shutterstock

Figure 1.
Global coverage, with local production facilities has been realised within a decade.

Summary

Shell is already active in the Power generation and distribution market for over 80 years, historically the product portfolio was based on traditional mineral oils (Diala AX, Diala B, Diala DX, etc.). With the introduction Shell Diala S4 ZX-I, based on GTL technology, the performance scope was pushed to the next level; higher flash point (safety), Sulphur free formulation (eliminate corrosive Sulphur risk), lower density (weight saving), superb oxidation resistant (long oil life/cost reduction) and easy recyclability (sustainability).

Obviously, for smooth the market introduction and acceptance, easy handling and continuity in oil condition monitoring best practices are important key points. Leading OEMs and customers have collaborated to closely monitor the important oil condition parameters (physical, chemical and DGA) and share the positive findings. Standard oil condition best practice remains valid with Diala S4 ZX-I.

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Johan Fournel

CEO of GMT International and Akhelec

Interview with **Johan Fournel**

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To translate my vision for the future, I would like to take the opportunity to talk about this new filter that we have recently put on the market, these 15-liters-per-minute ones.

Photo: GMT International, Akhelec


etatec

Alan Ross: My guest today is Johan Fournel. He is the CEO of GMT International and Akhelec. And we're going to talk about both companies. Johan, thank you for joining us.

Johan Fournel: My pleasure Alan.

AR You've been the CEO of GMT International for three or four years now, correct?

JF Well, I've been working for GMT International for the past twelve years. CEO, now for three and a half years. GMT international and its subsidiary AKHELEC are specialized in environmental protection of oil immersed electrical transformers such as metallic spill containment berms/retention bunds. Natural dielectric fire extinction devices, and oil rainwater filtration systems.

AR Tell me a little bit about your background and what got you into the transformer industry. How did you get involved in it, and what is your educational and work background?

JF My education is in chemical engineering. I started my career working for an oil company called British Petroleum, and then I switched to a service company, which is still in the oil business. I worked for ABB, but not in the electrical divisions, only in the petroleum division. I then had a good opportunity to move to automotive. In the beginning, I was optimizing fuel production at BP and ABB, and then I moved to the automotive industry to use the fuel, and somehow, I ended up in the electrical business.

AR Let's now talk about GMT International. GMT International is primarily in France and Akhelec is in the rest of Europe and the rest of the world. We don't have anything happening in the United States. We need to encourage you to come to North America and Canada but we'll talk about that at the end of the interview. Tell me about the two companies.

JF In the beginning, we only had GMT and that was in France. We started this company back in 1995, and a few years later the previous CEO decided to send someone to Spain to study the potential opportunities there. They then decided to launch a new company based in Spain in 2005 and this company was called Akhelec. After this, we started to develop the export business outside of France and outside of Spain. We first started working with Great Britain, Belgium, Italy, Switzerland, and then started doing overseas business. As you said, we are not doing anything in the US yet, but we have exported. We have been exporting materials to Latin America, to Asia, Australia, and New Zealand.

AR Are you selling mostly to the OEMs? For instance, are they taking care of that part of the installation process or are you selling to the final end customer?

JF I would say half and half. I mean, half of our business is done directly with the utilities, the end user, and about 50% is done through OEMs or Integrators or EPC, even EPC contractors.

AR I've been in the power industry for the last 15 years and honestly, I had never heard of a bund before. I've heard of different containment systems, but not a bund.

JF Maybe you don't call it the same way I assume you call it spill containment berms in the US.

AR Yes, that is exactly what we call them. However, when I figured out what a bund was, I thought, oh, it's a very high quality, and very unique. Tell me then what makes the bunds that you provide different than what we normally use which is a berm?

JF Traditionally most of the end users use concrete berms . This is what has been done for the past 50 years. Now we have come up with a different solution which is metal. It is a hot-galvanized steel berm with different advantages or disadvantages compared to concrete berms. Thanks to the metal berms, we minimize the onsite work, we deliver the bund and we can install a very large bund, around 70 m² or even larger within one or two-days max. If you build it in concrete, it will take weeks. It takes three or four weeks just for it to dry. So, it's quite a lot of time that can be saved thanks to the steel bund.

AR There is another issue with that. Concrete that is not allowed to cure creates all kinds of problems. Like when you put the weight of a transformer, an oil-filled transformer on top of concrete, if the ground hasn't been prepared, if the concrete hasn't been allowed to dry and cure properly, guess what happens? You put the weight on it, and the concrete cracks. So now that I know that there's a solution, well done!

JF It's a rapid solution on-site. I think the quicker you go on-site, the less risk of accidents or personal injuries you have.

Photo: GMT International, Akhelec


HERGON

“

100% of our business is in and around the transformer business.
So those filters have been specially designed to treat the water around electrical transformers.

New FILTRELEC® F15 filter is more economical, more robust and environmentally friendly.

“

AR You have a filtering system that you're introducing. Tell me a little bit about that.

JF Yes, so as you know, berms are installed underneath transformers. Whenever transformers are installed outdoors, the rainwater picks up traces of oil present on the transformer itself and collects in the berm. In order for the berm not to flood and overflow, you need to purify the water before draining it. If you use a safety syphon, your berm will remain full of water. That's something maintenance operators don't really like. When you work on a power transformer with cubic meters of water underneath it, it's not really safe. Also, the electrical standout across Europe and the US as a matter of fact requires you to have the berm as empty as possible in order to have space in case there is a huge sudden oil leak. And if such a massive oil leak does occur, you need to recover 100% of the oil inside the berm. For that to happen there needs to be as little water as possible in the berm. This is why few years back we developed a filtration system based on absorbing polymers.

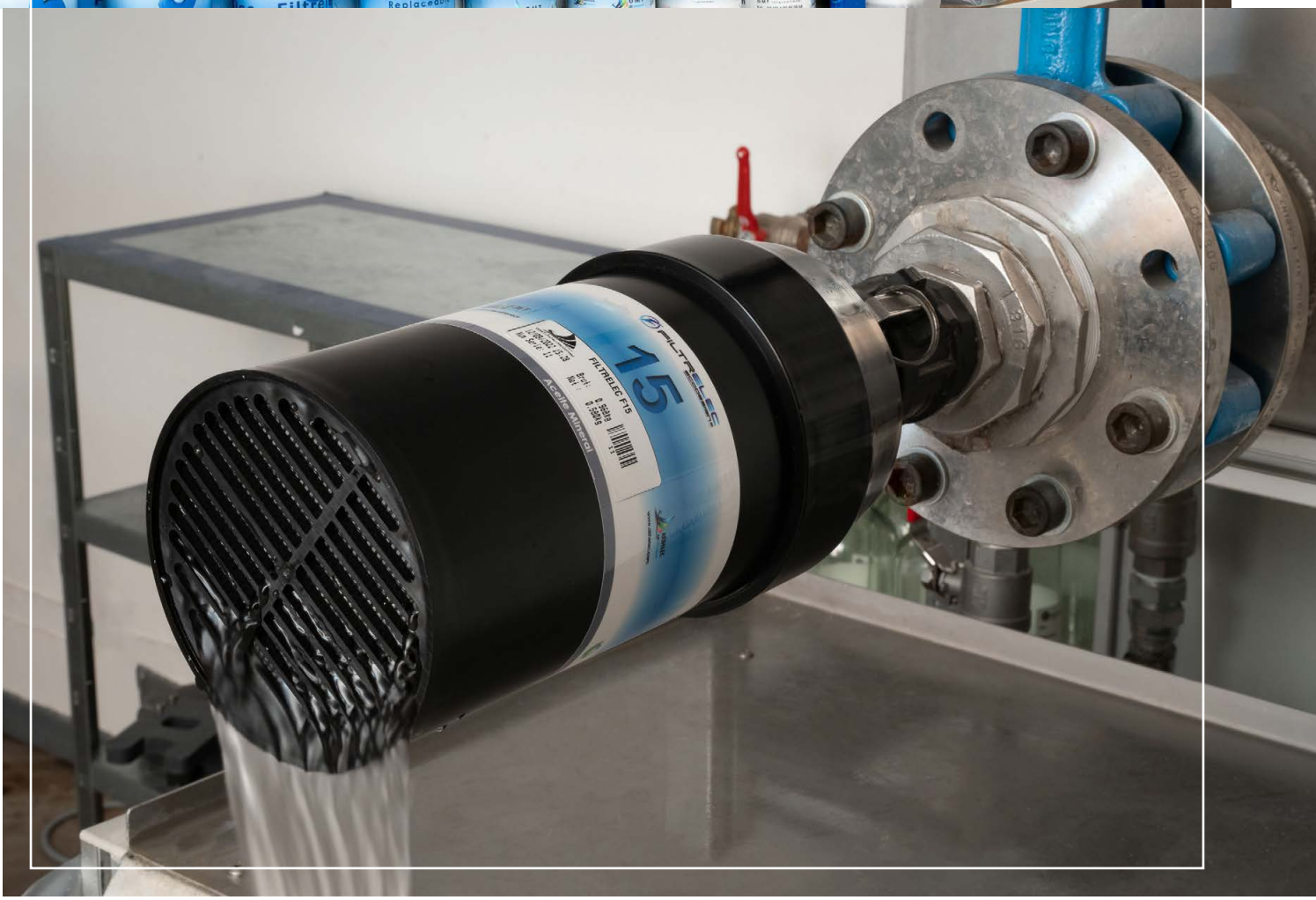
These are oleophilic polymers that don't like water at all. So, molecules of hydrocarbon are trapped in the polymer, whereas water can flow through it freely. This is basically how it works.

AR Your chemical engineering background just showed itself here, Johan. So, there is a problem with water but there's also a problem with contamination. I think all governments are getting very restrictive because any kind of leak, any kind of oil spill is a contaminant. You said the filtration system helps with that. Explain that a little bit more for me.

JF Yes, what you just mentioned, Alan, is called the Clean Water Act in most countries. Each time you release rainwater or processed water into nature, you must first make sure that you're not going to pollute anything. Therefore, you need to make sure that the water does not contain hydrocarbons. It is as follows, in certain areas, the maximum hydrocarbon content in the released water has to be lower than ten milligrams of hydrocarbon per liter of water. And in other areas or specific countries, the hydrocarbon content has to be less than five milligrams per liter. This is a standard. Those five milligrams per liter is the standard we follow. Now, we have developed this filtration unit based on this standard. So, we usually release the water directly into the substation gravels, or we have lots of projects with hydraulic plants, and we drain the filtered water directly to the river, making sure that it contains less than five milligrams of hydrocarbon per liter of water.

Photo: GMT International, Akhelec


FILTRELEC
15
5
Filtrelec
Replaceable
Cartridge
GMT


FILTRELEC
15
FILTRELEC F15
ACEITE MINERAL

AR Today society is very concerned about pollutants getting into the water. So, when you talk about a five milligram per liter of release, I can't fathom what scale that is, because if you tell some people, hey, there is any number of hydrocarbons floating into the river, they're going to get upset. Now you are following a stricter standard than what is required in North America.

JF I think California has five milligrams per liter.

AR California leads the way in prevention and assumes everybody will move that way.

JF But to answer your earlier question about what that means: Five milligrams per liter is maybe a 10th of a *drop* of oil in a liter of water.

AR All right. That's a scale that I can understand. Johan when we were prepping for this interview there was a word that came up. It's *hydrophobic*. Explain what hydrophobic means, please.

JF Hydrophobic means that the product doesn't like water at all and does not react with water at all. So, there is no reaction at all between the absorbing media and the rainwater.

AR Talk about the range of the rainwater filtration systems you've got.

JF We have different filters. The smallest one is five liters per minute water flow rate. Then we have a brand-new filter that we are now putting on the market, which is 15 per minute. Then we have 1,500 liters per minute and all of these work on gravity. We also have a pump system for maintenance activity that is about 50 liters per minute.

AR And those applications are transformer-related?

JF Yes, they are, Alan. 100% of our business is in and around the transformer business. So those filters have been specially designed to treat the water around electrical transformers. New FILTRELEC® F15 filter is more economical, more robust and environmentally friendly.

AR My final question for you is a vision for the future. You're the CEO, you must cast the vision and leadership for the future of the company. What's your vision for the future of GMT and Akhelec?

JF To translate my vision for the future, I would like to take the opportunity to talk about this new filter that we have recently put on the market, these 15-liters-per-minute ones. They are called F15, and the reason they are my vision for the future is that we developed this filter to be more environmentally friendly. The housing of this filter has been totally redesigned and, in the end, it offers about 70% mass reduction compared to the main products available on the market. We end up with a reduction of fuel consumption to transport the product and we end up with a reduction in the weight of waste generated when the product is being saturated by oil. Therefore, this is part of my vision for the future. We all have a role to minimize the footprint of our activities on the environment. And that is my vision; to minimize our footprint on the environment and try to use our minds better to end up with a more environmentally friendly product.

AR Product development then has to be one of the benchmarks of what you're doing. You got to keep making what you're making, but at the same time, you have to do the product development in order to come up with improvements. How did you do that?

JF In the beginning, we had PVC casings, and we have already equipped very large solar farms in Australia, Mexico, in other countries. And after a few years, when we get photos or when we go on-site, after two or three years and we see our product being seriously damaged by UVs, to the point where there's no color anymore. But sometimes it can even break the plastic. If you expose your product to UVs, after one or two years, the weight of the product itself breaks. And this was the starting point of this new development.

We understood that PVC is not the solution. I mean, if you want to have a product that stays outside, that is exposed to UV rays, you cannot use such PVC, even though it's pressure PVC or reinforced PVC, you just delay the problem. We then decided to think about and study other plastic casings that can handle UVs much better.

AR That's a great vision. Well done. Again, I would like to thank Johan Fournel for joining us today.

JF Thank you very much Alan.

Photo: GMT International, Akhelec

A BETTER ENERGY FUTURE IS A FUTURE OF COLLABORATION

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MERVE MADEN AVCI

CHAMPIONING AMBITION FOR WOMEN

Merve Maden Avci is Product Line Manager for Electrical Systems and Solutions EMEA at Eaton, the power management multinational dedicated to improving people's lives and the environment with technologies that are more reliable, efficient, safe and sustainable.

Source:
Merve Maden Avci

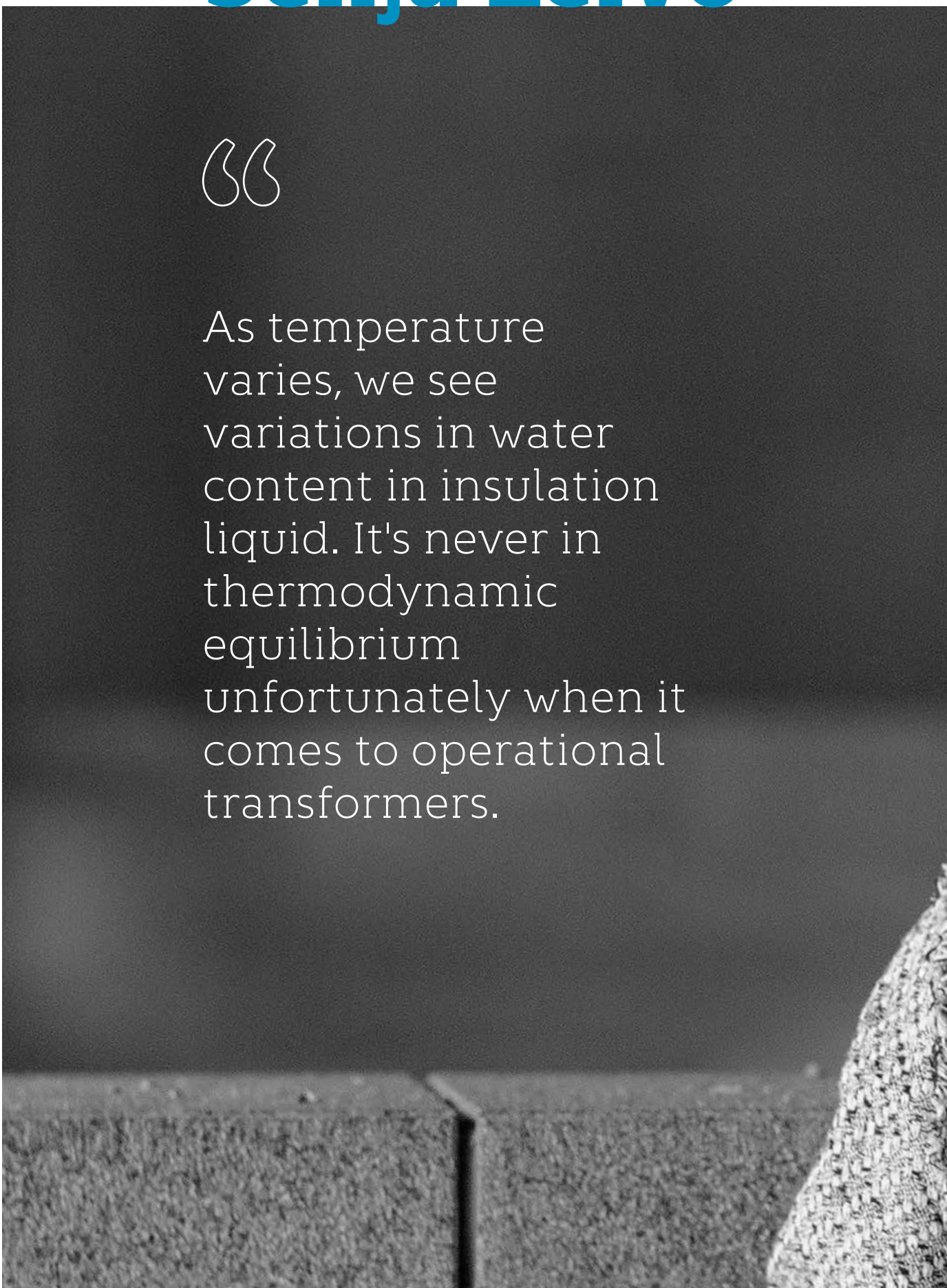
Merve has been living and breathing electrical transmission and distribution for 11 years, first as a design engineer before switching to the sector's commercial side – and now as Eaton's lead for EMEA medium and low voltage solutions across strategy, positioning and pricing. **Her career has been a fast-moving journey in every sense, previously leading tendering, sales and marketing teams throughout EMEA and the Americas.** She has also managed market entry strategies, sales operations, business development and operational improvements with a 6 Sigma project implementation which was the subject of her Masters' thesis. **Plotting Eaton's product development roadmap to meet customer needs is a critical dimension of Merve's current portfolio.** This includes shaping product strategy deployment for medium and low voltage products and transformers, as well as managing the profitability of the portfolio. **It also extends to recommending, developing and pursuing long-term strategy and actionable objectives for the EMEA product line – ensuring it's aligned to the overall global product line strategic direction.** Through collaboration with R&D, segment and sales teams pursuing Eaton's growth ambition in the core segments, in cooperation with operations and supply chain. **As Merve has evolved her career, she's been inspired by strong female leaders, identifying in particular with themes Facebook former Chief Operating Officer Sheryl Sandberg explores in her celebrated book 'Lean In'.** The 'likeability bias' that sees successful men liked, while successful women are deemed pushy is just one of the many challenges ambitious women face that Merve is determined to address and overcome. **Now actively sponsoring female talent in her current role, both inside and outside the company, she's keen to increase awareness of the hurdles women face in the workplace.** Merve feels very much 'at home' at Eaton where the company's commitment to changing the mindset around equal opportunities and the gender gap are clearly paying off. **She believes strong female leaders within the company have been key to setting a positive example – one that's now driving her own aspirations to take her career as far as she can.** Merve studied in Germany and Turkey. She has a BSc in Electrical Engineering, and an MSc in Engineering Management. **Outside of work Merve enjoys spending time with her daughter for whom she wants to set the good example of being a strong and independent professional as well as a happy and loving mother.** She also loves travelling, rowing at sunrise, laughing with her family and playing FPS console games.

Photo: Merve Maden Avci, rawpixel.com

Senja Leivo

Senior Industry Expert
at Vaisala Oyj

Interview with **Senja Leivo**



“As temperature varies, we see variations in water content in insulation liquid. It's never in thermodynamic equilibrium unfortunately when it comes to operational transformers.

VAISALA

Moisture in solid insulation, the bane of dielectric strength

Photo: Vaisala

Alan Ross: My name is Alan Ross, I am the Managing editor of APC Technologies, and my guest today is Senja Leivo from Vaisala.

Senja Leivo: Thank you, Alan.

AR I'm going to ask you a true or false question as a scientist. Every 1% increase of moisture inside of a transformer degrades the paper by half. True or False?

SL Yes, I would agree, this is like a rule of thumb.

AR This was an IEEE statement 20 years ago, and most people don't realize it. Whether it's by half or 20%, what it really says is *moisture* in a transformer is not good, correct?

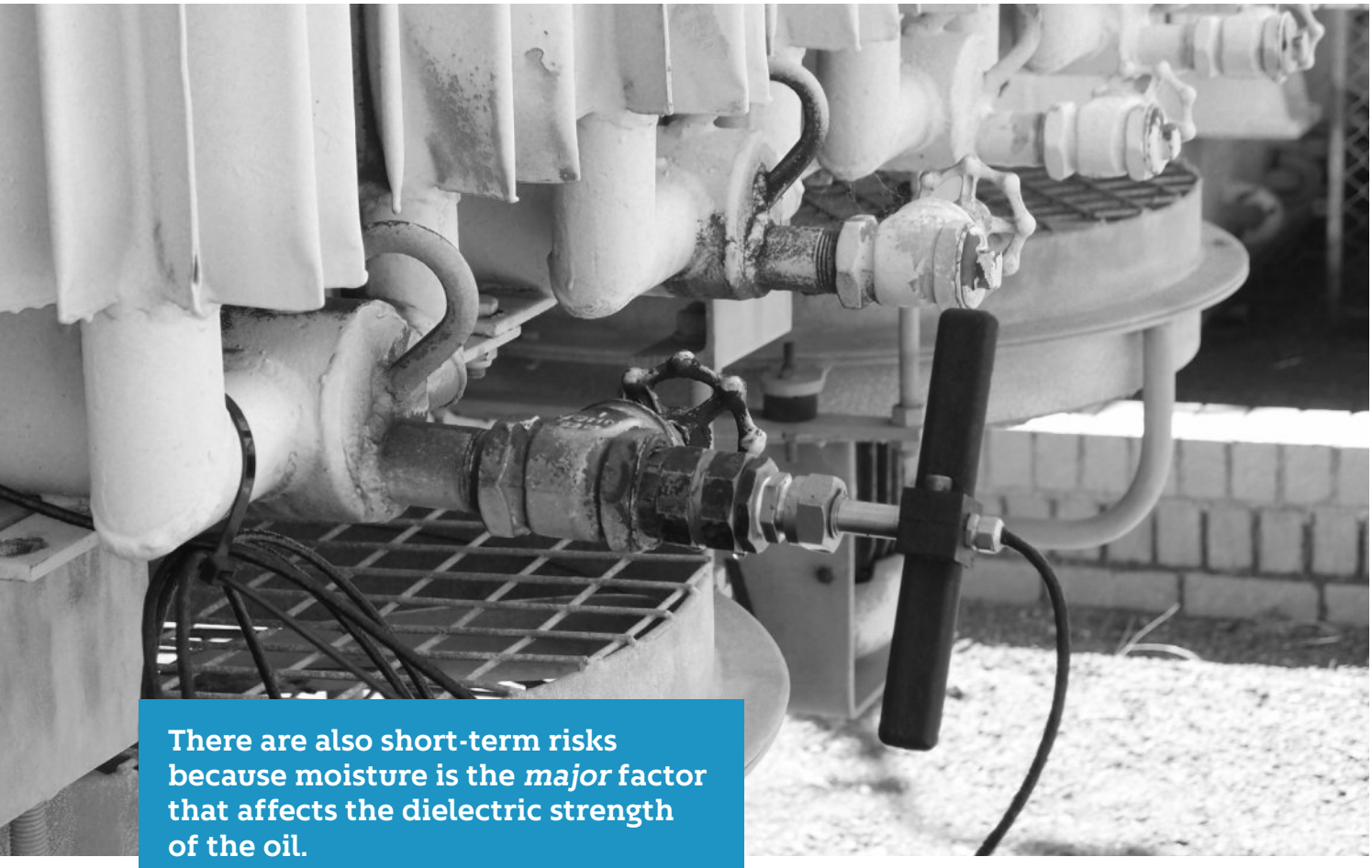
SL Yes, exactly.

AR Where does the moisture come from?

SL After factory drying, there is always residual moisture, which is very small. However, it is very difficult and noneconomical to dry it completely. Transformers are really dry when they arrive on-site, and during the lifetime of the transformer, I would say the majority of the moisture comes from the surroundings, either from ambient air humidity or some rare cases rainwater.

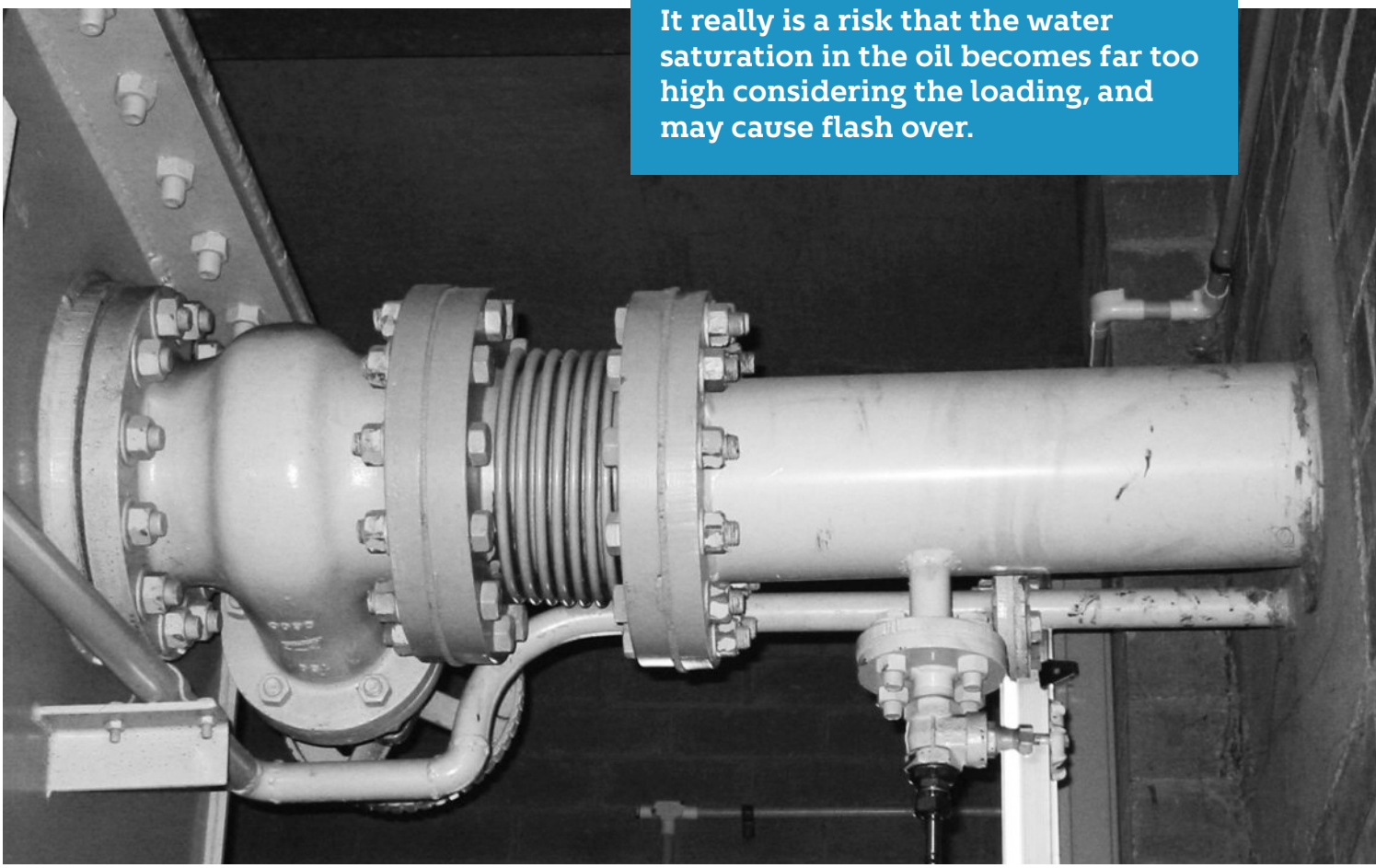
AR Okay. Most of the insulation products are cellulose based in transformers. And as I understand it, there's more moisture potentially trapped in the cellulose than there is in the oil. The oil may be dry, but if the cellulose has got moisture in it, as you said, that's going to migrate out. Talk about moisture in general as it relates to transformers and operating transformers. Just give me a primer on that.

SL It's exactly like you said Alan, cellulose materials especially insulation paper are very hygroscopic. The water will go there, regardless of the insulation liquid, whether it's mineral oil or esters. And only a small portion of the water is in liquid. It's said that 99% of the water is in solid insulation, and when the transformer is operated and when the temperature varies, some of the water is released from the insulation paper surface to the insulation liquid,. Therefore, if we follow the water content in liquid in real-time, we can see fluctuation. As temperature varies, we see variations in water content in insulation liquid. It's never in thermodynamic equilibrium unfortunately when it comes to operational transformers.



There are also short-term risks because moisture is the *major* factor that affects the dielectric strength of the oil.

Photo: Vaisala



It really is a risk that the water saturation in the oil becomes far too high considering the loading, and may cause flash over.

AR Here's the problem. I don't think the industry understands how bad this is because I talk to people and ask them if they test for moisture in their transformers. They respond with "Why would I do that?" I think there's a real ignorance about the damage that moisture in transformers does.

SL There are basically two major issues. One is the paper degradation in long term, as you mentioned. The other issue is more related to the operational conditions of the transformer. There are also short-term risks because moisture is the *major* factor that affects the dielectric strength of the oil. Especially if we have a wet transformer that has a lot of water in its solid insulation.. Then in some conditions you may be at risk of having a breakdown because of moisture in the oil.

AR What's the problem with the annual or quarterly or semi-annual lab testing as it relates to moisture?

SL It's often that the sample is just once a year or once in two years. As I mentioned, the moisture is exchanged between oil and paper. It's continuous, and you may not see those extremes with periodical samples. Also, quite often the samples are missing the temperature information, and in order to be able to evaluate the meaning of the water content in the oil, you really have to know the oil temperature, when the sample was taken because like I said, it varies a lot.

AR Talk to me like I'm a risk manager at a company and explain to me what the risk to my company would be and to my asset which is the transformer if I don't manage the moisture.

SL If it's an older transformer, and if the solid insulation has a high level of water, or if that transformer needs to be loaded heavily for some reason - Let's say there is a sister transformer that needs to be put out of service, and all the load is put to the other one which is wet. In this case, with such a quick high loading, the water is pushed from the solid insulation into the oil. It really is a risk that the water saturation in the oil becomes far too high considering the loading, and may cause flash over. Another similar issue may occur. If we have a wet transformer that was out of service for a while and when it's put back online and loaded quickly, the oil is still cold it cannot hold that water that is pushed from the winding insulation. And you can really have a so-called "raining" in a transformer. That for sure will cause a breakdown.

AR I want to switch gears a little bit. We're trying to decentralize energy, right? We're trying to go wind and solar. Those transformers become more like inverters than transformers because they must take power in. Is there a greater risk to an inverter-based system because of moisture, or is it just the same? What do you think?

SL If we only think about the basics, like thermodynamics it's the same, it doesn't matter which direction it goes. If it's a question of moisture, it's a question of temperature, it's a question of the materials involved. But all in all, I would say it's the same.

AR My next question then is, how do I mitigate the risks of moisture in transformers?

SL The first thing I would say is to get a good picture of the moisture levels, and the overall moisture dynamics in a transformer by having online monitoring to really see what is the moisture level during the normal operating conditions of the transformer, and if there are risks like the relative saturation of moisture going too high. One option would be to apply an online dryer to that transformer.

AR IEEE has now made passive drying one of the *primary* functions of eliminating moisture in a transformer. And there's a lot of them, a lot of them being made by different companies. It's a cost-effective way as it really works. Moisture tends to escalate and it tends to move with temperature, load, and everything. Therefore, it's the trend lines of moisture monitoring.

SL Yes, that's true. But even following trend is challenging because the desorption of moisture from paper to oil is faster than the absorption of water back to paper. So just comparing temperature and moisture levels is not so straightforward as you would think. But obviously, when you have real-time monitoring and you have the loading data and you have the temperatures, you can get a clear picture of the overall moisture household in the transformer and if there are risks involved short term or long term.

AR Vaisala is arguably one of the world leaders in monitoring technology. Tell me about what has happened in the whole monitoring as it relates to moisture. What technology should I be looking for?

SL I think nowadays basically all online moisture sensors are using the same technology principle, which is the capacitive moisture sensors, which basically measure the relative moisture saturation of oil and the temperature and if needed it calculates the absolute water content as ppm.

We started doing real-time monitoring 20+ years ago. If I look back at that time, it was more challenging to convince the asset owners that online monitoring of moisture could be useful.

We started doing real-time monitoring 20+ years ago. If I look back at that time, it was more challenging to convince the asset owners that online monitoring of moisture could be useful.

AR We both agree that moisture in transformers is often overlooked, and misunderstood and it's a real problem that transformer owners, and transformer operators really need to know about. There is no way to deliver a transformer that is completely moisture-free unless you want to pay a lot more money than you already do for the transformer. Therefore, the idea of monitoring moisture is an important one. It is one that can be coupled with DGA monitoring so that it becomes simpler, but it gives you the data and the information that you need in order to make a decision. Is that a fair statement?

SL Yes, I would agree. But even more, I would say that for new transformers, I really encourage the asset owners to pay attention to the early life of the transformers because like I said, the moisture comes from the surroundings. And by taking care of the breathing systems, taking care of the dehydrators of the breathing systems are in good condition, you can really extend the life. But once the transformer is already wet and

has high water content in its solid insulation, then I would say the online monitoring becomes more and more important because that's where the operational risks may come up.

AR Last question, moisture in oil, moisture in esters. Is there a difference between oil and esters in terms of what happens with the moisture? Is it better? Is ester a better solution to treating moisture and transformers at the beginning? Or is that a myth that esters are better?

SL That's a question I've been asked a lot, and I don't want to take any specific opinion. However, looking at this from a scientific point of view, it's true that esters, synthetic or natural, have much higher water solubility than mineral oils. But after all it is water content in paper and transformer temperature that determines what will be the relative moisture saturation in insulation liquid whether it is mineral oil or ester.

AR Okay, great thank you very much for that answer. This has been a great interview. Thank you for the work that you do and thank you for willing to share that with us at APC Technologies.

SL Thank you, Alan, it was a pleasure to be here.

Photo: vaisala

Once the transformer is already wet and has high water content in its solid insulation, then I would say the online monitoring becomes more and more important because that's where the operational risks may come up.

6 Things Every Transformer Owner Should Know About: Dielectric Breakdown Voltage

by **Andy Shkolnik**
Jason C. Dennison
and **Ryan Tate**

Technical Authors
from SDMyers

When it comes to the ability of your transformer's insulating liquid to withstand electrical stress, there are some things you should know about dielectric breakdown voltage.

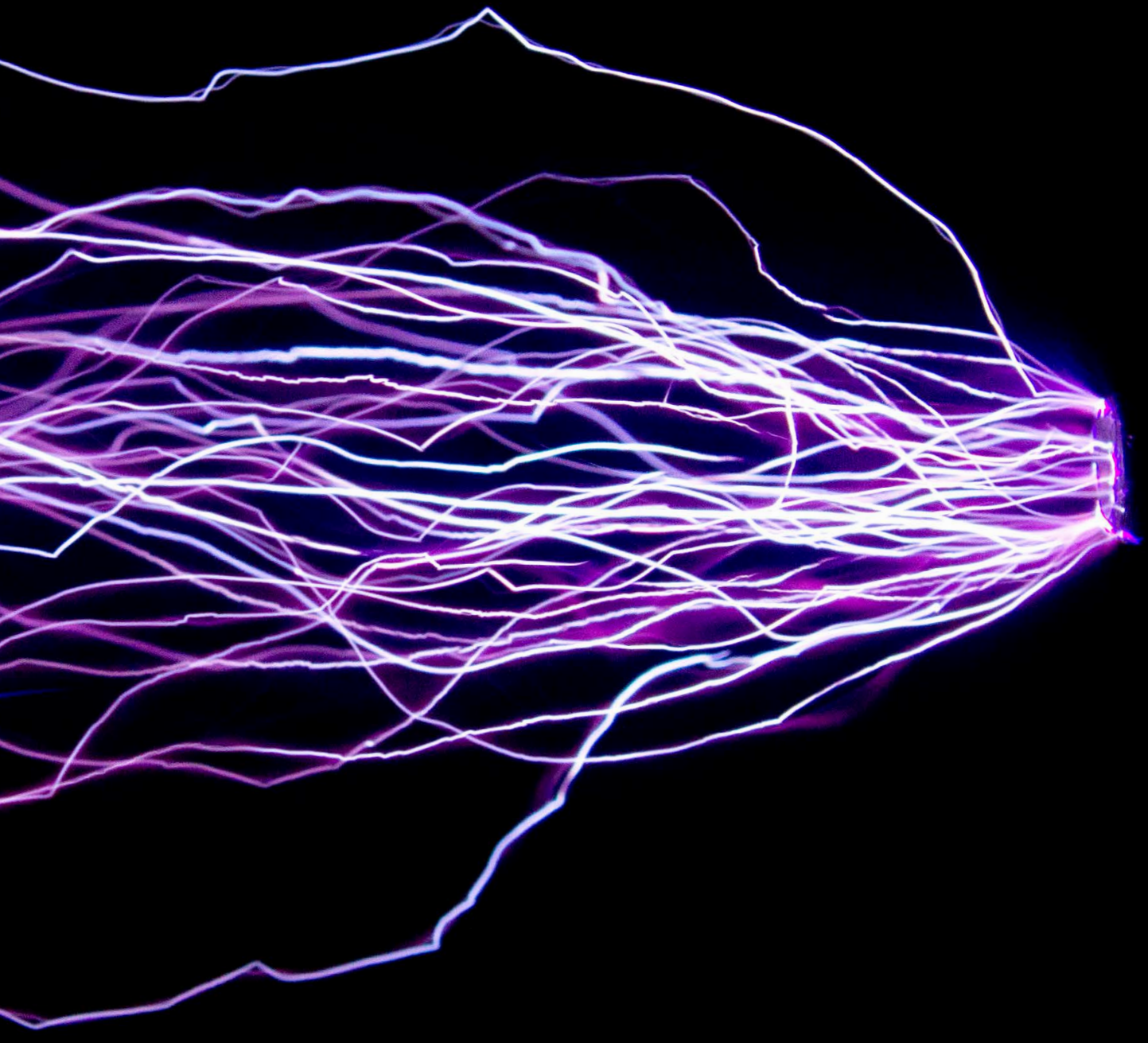
1

What is dielectric breakdown voltage testing?

A dielectric breakdown voltage test measures the electrical stress an insulating liquid can withstand without "breakdown"—when

Photo: Shutterstock

Here are six things every transformer owner should know about dielectric breakdown voltage.



electrical potential is high enough to cause discharge through the dielectric liquid. This test is used to evaluate a liquid's ability to withstand electrical stress and can be performed for accepting new insulating liquids or evaluating in-service insulating liquids. The test is performed using a test cell with two electrodes spaced with a predetermined gap between them.

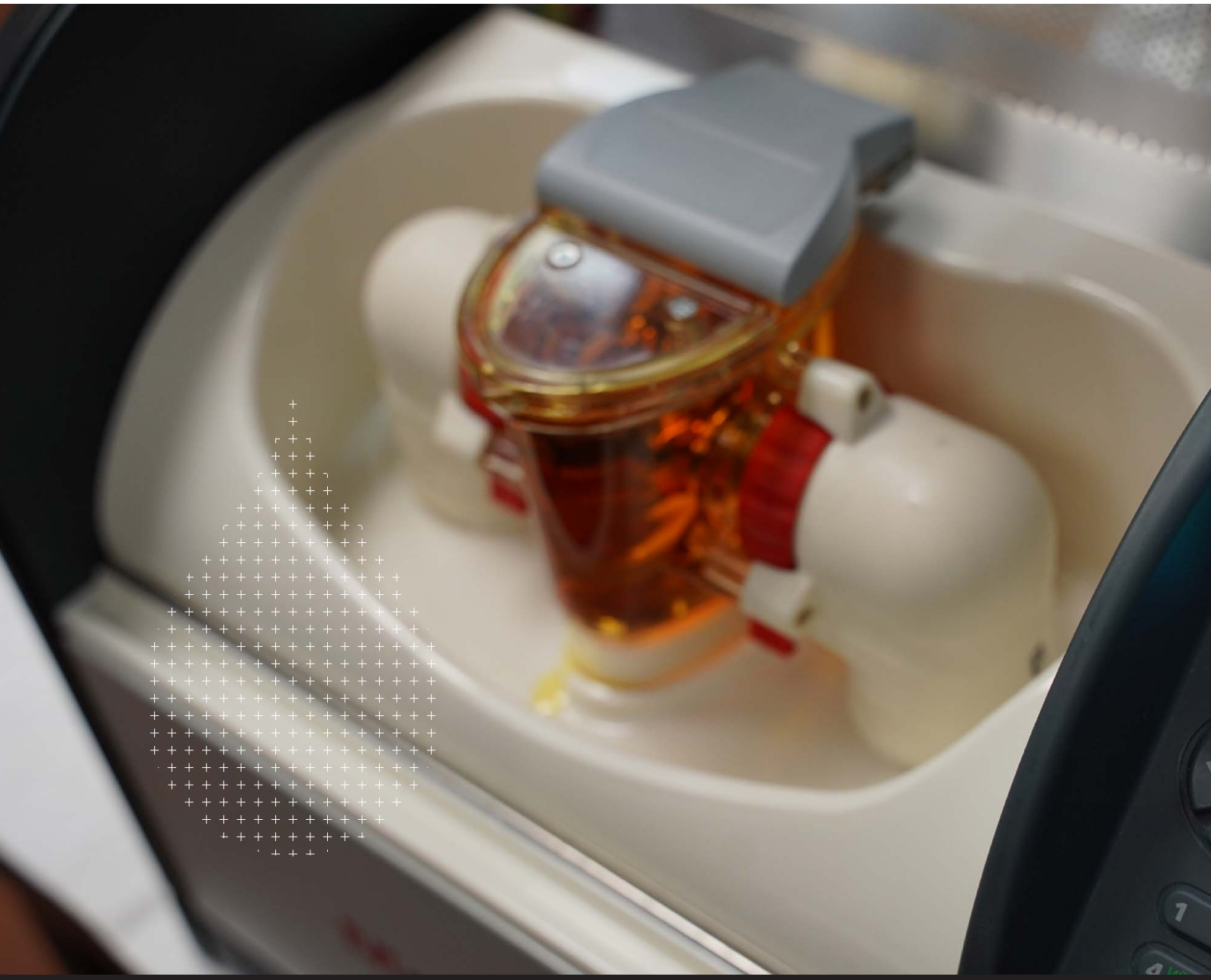
A sample of the liquid being tested fills the test cell, and the two electrodes are subjected to a steadily increasing electrical potential until there is a discharge through the liquid from one electrode to the other. The voltage level at which the breakdown occurs is recorded as the test result and compared to acceptable levels. There are different methods based on which test standard is used (D877, D1816, or IEC 60156, more on these later). The standard defines the test method and parameters required to conduct each test. These parameters are the rate at which the test voltage is increased, the size and shape of the electrodes, the gap size between the electrodes, how many times the test is repeated, and whether or not the liquid is stirred during the test.

2

Why should you perform dielectric breakdown voltage testing?

For in-service transformers, the dielectric breakdown voltage test is one way to detect contamination in the liquid before it leads to a catastrophic failure. Contamination of the liquid due to such things as fibers from the solid insulation, conductive particles, contamination by foreign matter, dirt, and water can affect the dielectric breakdown voltage. When done in conjunction with other tests, the test results can help you assess a transformer's overall reliability and lifespan.

The test can also be performed on new, reprocessed, or reconditioned insulating liquids before being used to fill equipment. Acceptable test results are necessary (but not sufficient by themselves) to ensure that the liquid was stored and transported properly.



3

Which types of insulating liquids can be tested?

For a long time, our industry has used the generic terms "oil" or "fluid" when referring to a transformer's insulating liquid. Regardless of which type your transformer contains, each is subject to contamination, the presence of conductive particles, aging, and moisture. There are five common insulating liquid types found in transformers.*
They include:

- Mineral Oil
- Silicone Fluids
- Natural Ester (vegetable oil) Liquids
- Synthetic Ester Fluids
- High Molecular Weight Hydrocarbon (HMWH) Liquids

Note: This list represents broad categories of the most common liquid types. Additional types can be tested but are relatively rare. Consult a transformer specialist if you have questions.

Photo: SDMyers

4 How often should I test for dielectric breakdown voltage?

Dielectric breakdown voltage testing should be essential to your regular transformer maintenance and reliability program. It is recommended that your insulating liquid is tested at least once a year, with the test results being recorded to track trending results. Understanding the trend of your data will help you identify sudden or unexpected changes and plan accordingly with preventative maintenance actions.

5 What are the different test standards?

ASTM D877 – The D877 method uses two flat disk electrodes with sharp edges spaced 0.10 inches (approximately 2.54 mm) apart. The rate of voltage increase is 3,000 volts per second. D877 has limited use in measuring water contamination in insulating liquids because it is not sensitive to moisture at saturation levels below about 60%. It is sensitive to contamination by some other materials and to the presence of particles in addition to high moisture levels. It does not do a good job of detecting oxidation decay products.

ASTM D1816 – The D1816 method has been used by many standards organizations to replace the D877 method as both a new liquid test and as an in-service liquid test because the VDE electrodes more closely resemble the geometry of conductors

inside operating electrical equipment and because the test is much more sensitive to moisture and cellulose particles. There are two possible gap settings for the electrodes: 1 mm (approximately 0.04 inches) and 2 mm (approximately 0.08 inches). The rate of voltage increase is 500 volts per second. A difficulty with this method is that it is also sensitive to dissolved gases, which may not present any operational problem at levels that affect the test. So, while an acceptable D1816 value can be interpreted as an indication of normal operation, a questionable or unacceptable value may not automatically be interpreted as a definite sign that something is wrong.

Further investigation would be required.

IEC 60156 - Standard 60156 uses electrodes that are similar geometrically to the VDE electrodes used in ASTM D1816. The spherical electrodes are spaced 2.5 mm apart, and the rate of voltage increase is 2,000 volts per second. The method in Standard 60156 allows the optional use of an impeller, operating similarly to the one used in the D1816 method, except that it operates at 250 to 300 rpm. The IEC method also allows the use of a magnetic stirrer operating at a similar rate if there is no significant chance that magnetic particles will be removed from the liquid.

The presence of magnetic particles would affect dielectric breakdown in the transformer, so removing those particles by the stirrer during the analysis would yield unrepresentative values.

For several years, the ASTM D877 test was regarded as the standard way to perform the dielectric breakdown voltage test on insulating liquids for electric power equipment. In recent years, organizations such as IEEE and ASTM have compared it to ASTM D1816 and found that the D1816 test provides more accurate results for determining the dielectric characteristics of liquid inside power equipment.

6

What does a "bad" test result mean?

When we evaluate results outside the acceptable range, the first consideration is to cross reference the results to moisture, liquid power factor, and liquid screen tests to identify possible causes for the depressed dielectric breakdown voltage values. The dissolved gas analysis is also consulted to determine whether the gas content could have depressed the levels outside the acceptable range.

Frequently, we can eliminate moisture, liquid aging, and most types of contamination as probable causes for poor dielectric breakdown voltage results. In such cases, the cause of the results would generally be either excessive gas content or an abnormally high number of suspended particles in the insulating liquid. If gas content is not excessive, the appropriate response is to repeat the dielectric breakdown voltage determination on another sample. If this second sample also has an unacceptable result, a particle count distribution test should be performed using the standard method ASTM D6786. This is generally sufficient to establish the cause of the abnormal dielectric breakdown voltage results.

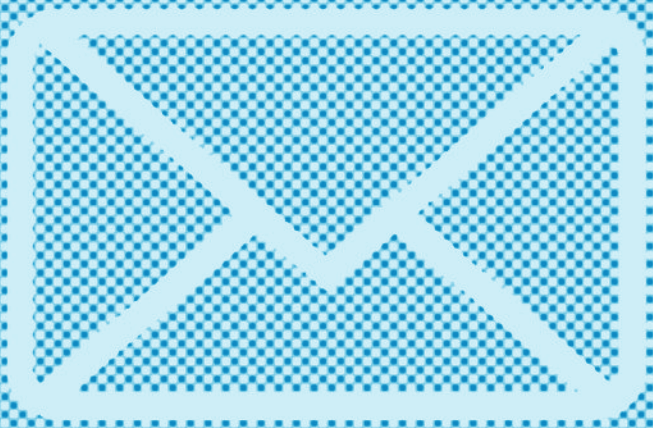
Invest in Reliability

No single test is sufficient to define all known conditions and provide transformers owners with everything they need to know about the health of their equipment. Because the dielectric breakdown voltage test is all about identifying the presence of contaminants in insulating liquids, it is, however, a critical piece of the puzzle regarding your electric power system's overall reliability and performance.

When gathered over time alongside other essential tests and maintenance activities, transformer owners can use the dielectric breakdown voltage test data to track trends and act when needed. The information you gather helps you predict your equipment's lifespan, reduces the risk of failures, increases safety, and is an investment in your overall reliability. That means less downtime and saving time and money for your organization.

Photo: SDMyers

KEEP IN THE LOOP



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Dialectric Oils & Fluids
PART 2

Once again, like last year, we have had more great content than space to place in the Digital Magazine for December so we have split the Insulation and Oils & Fluids issue into two editions, December and January.

Once again we would like to thank our digital community for your ongoing support.

Best Wishes to you all and see you in the New Year.

Alan Ross, *Technical Director and Managing Editor,* APC Media

COMING IN JANUARY ISSUE

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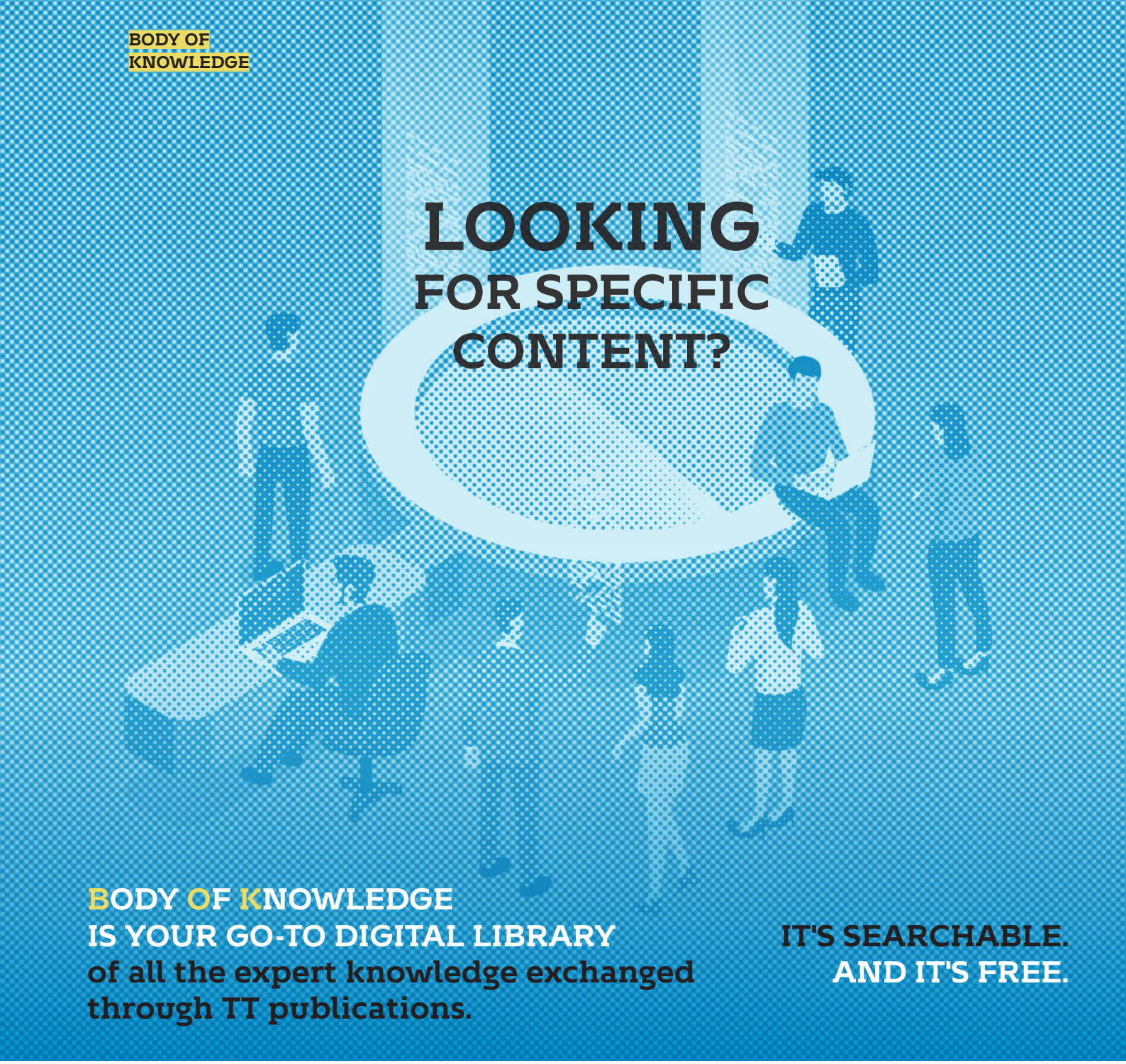

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