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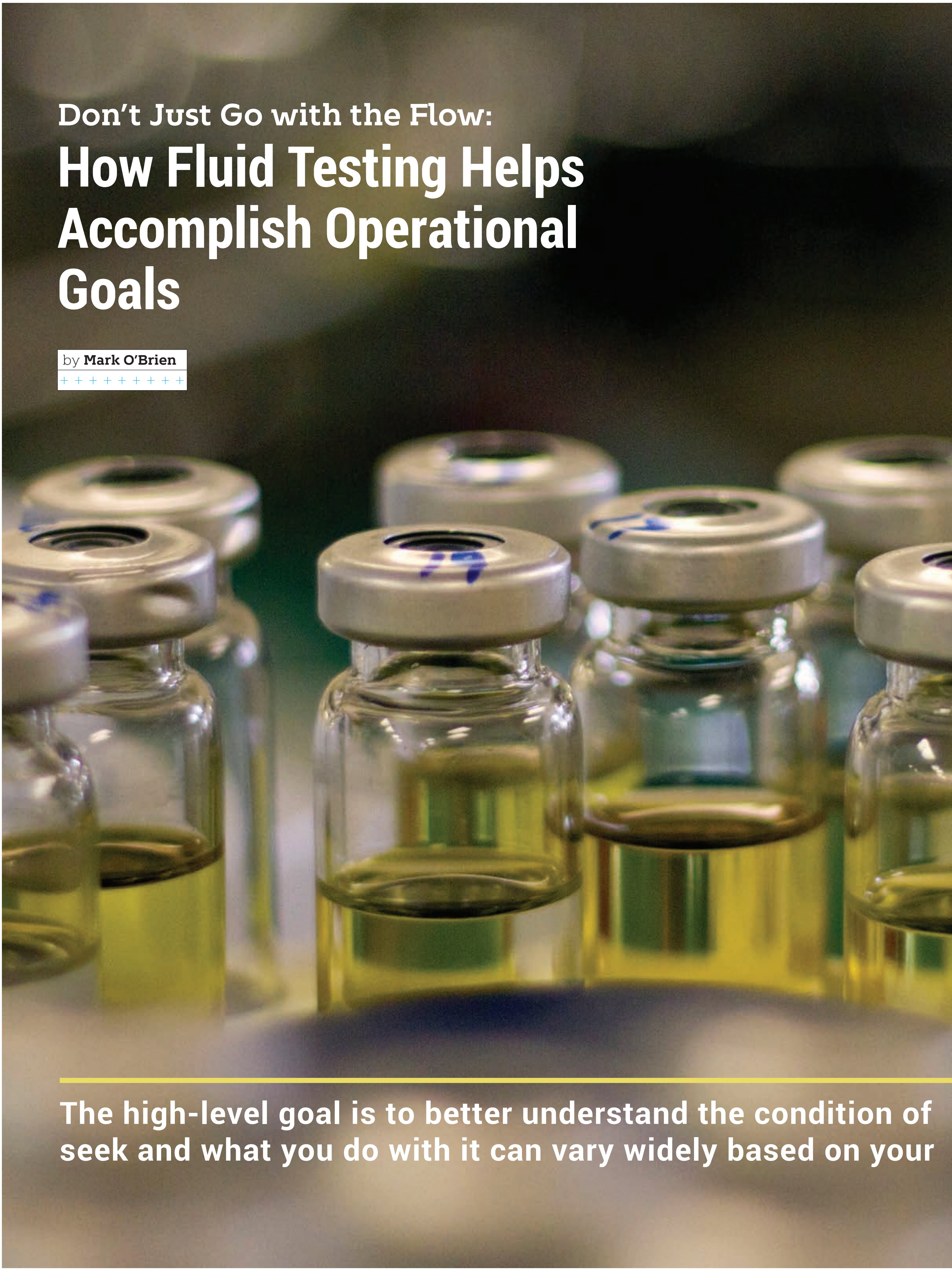
Transformer Oils & Fluids

Development of Transformer Fluids Over the Last Century

Interview with **Patrick P. Ryan**
Executive Director at **IEEE PES**

Interview with **Jason Dennison**
Senior Manager Laboratory and Diagnostic Services at **SDMyers**



Don't Just Go with the Flow:

How Fluid Testing Helps Accomplish Operational Goals

by **Mark O'Brien**

The high-level goal is to better understand the condition of seek and what you do with it can vary widely based on your

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Quick, don't think, just answer – why are you testing your transformer fluid? Is it because your insurance requires annual testing? Or, because that's what your operation has always done? Perhaps you know it improves reliability... in some abstract way. If you can't answer the question succinctly and immediately, there's a good chance you're not getting the most out of your fluid testing protocol. **Routine testing can be time-consuming, cut into your maintenance budget and even pose potential safety issues, so identifying your operational goals and creating a fluid testing plan that supports them is essential.**

Photo: On Now Digital

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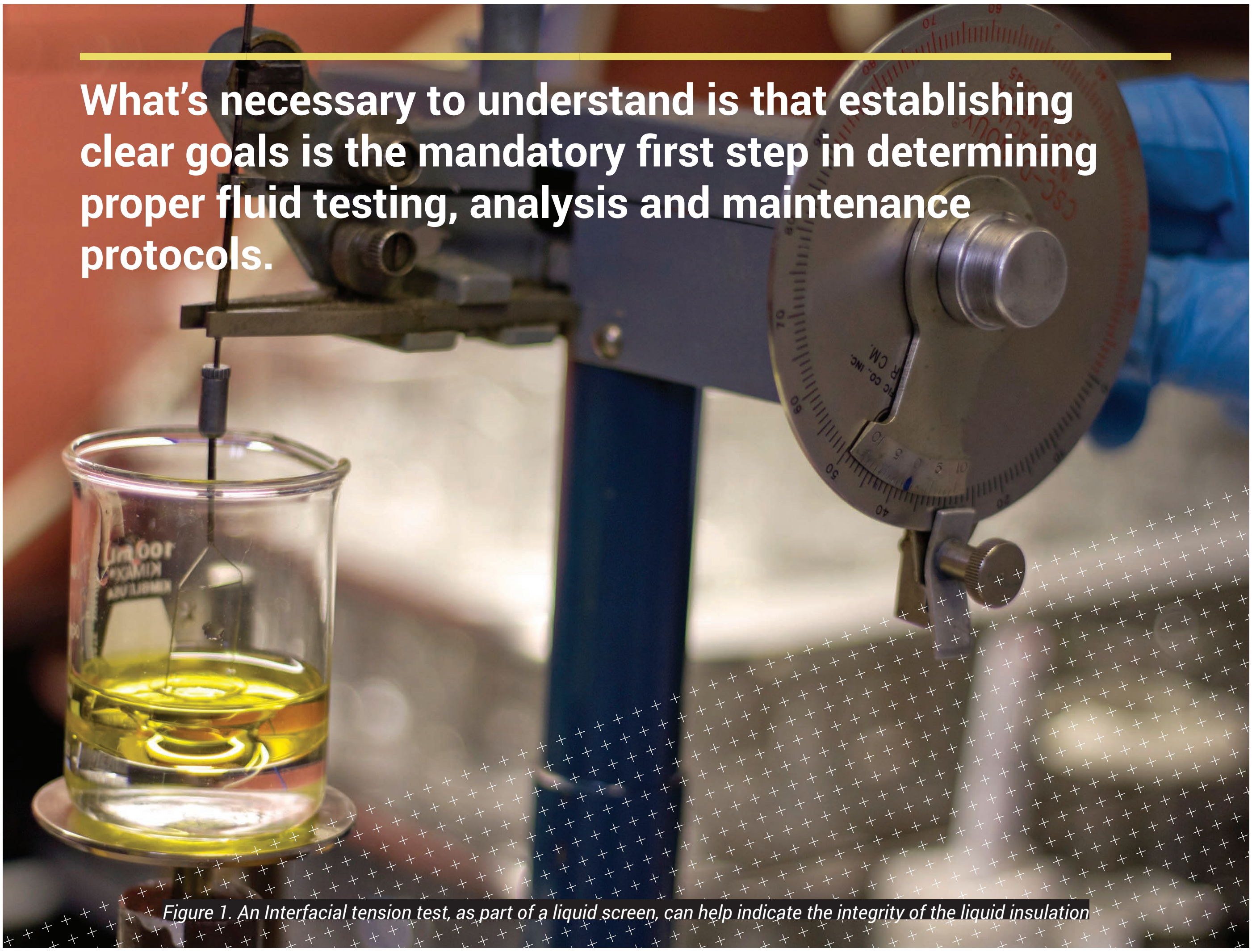

Figure 1. An Interfacial tension test, as part of a liquid screen, can help indicate the integrity of the liquid insulation

You wouldn't let your doctor's office draw a blood sample if you went in for a flu shot, would you? And I'm guessing you wouldn't undergo an invasive scan if you suspected you might have poison ivy. Just like your doctor's focused health assessment, your fluid testing plan should be strategically tied to your business goals. The high-level goal is to better understand the condition of your equipment. However, the specific information you seek and what you do with it can vary widely based on your organizational goals.

What Can You Learn from Fluid Tests?

Before you start pinpointing goals, it's important to understand that fluid testing ultimately gives you two types of information. The first relates to the degradation of your transformer's insulation, and many annual fluid tests, such as an interfacial tension test (Figure 1), track this. The second results from fault probing within your unit. This is most valuable if done on an instantaneous basis, but when performed over time, these test types can also indicate your equipment's operating condition. In either case, the fluid is simply an indicator of the equipment's condition. Ensuring the liquid insulation is in good shape is important, but the solid insulation should be your true concern. When the solid insulation goes, end of life is imminent. With that understanding, let's look at how you can make fluid testing an active player in your maintenance plan.

Goal Setting: Identify Your Operational Aims

Don't think about fluid testing specifically when you assess goals; rather, consider the overall aims you're trying to accomplish. Common aims for industrial and commercial operations include:

- Decreasing capital expenditure
- Extending asset life/reliability
- Improving safety
- Limiting downtime
- Increasing efficiency
- Maintaining compliance

What's necessary to understand is that establishing clear goals is the mandatory first step in determining proper fluid testing, analysis and maintenance protocols. This is because your goal affects the test types and tools you'll need to be successful.

If, for example, your organization's only goal is compliance, your service provider will most likely limit the testing scope and depth of analytics and keep follow-up actions minimal. However, if your goal is improving reliability while limiting capital expenditure, your equipment will require more stringent testing. You may even consider using AI to uncover optimal operating conditions. It's a completely different task, using completely different tools. **There is a full spectrum of goals and outcomes. And depending on which you choose, your approach will vary wildly.**

Photo: On Now Digital

More data leads to more insight if you have the right tools. Just bear in mind that without the right tools, it often results in chaos and confusion.

Figure 2. Laboratory technicians preparing testing samples for MaxLife analysis

Process Definition:
What, When and How Often?

Once you've set your goals, you'll face a new set of questions, mainly: what pieces of equipment are you going to test, and how frequently are you going to test them? **A strategic fluid testing plan is rooted in implementing a result-oriented process.**

First, determine which pieces of equipment you receive the most value out of testing. You can accomplish this completing a basic criticality analysis. This enables you to start testing the most critical pieces of equipment first. Just note that in many cases, you may be required to test all pieces of equipment above a certain voltage per your insurance provider.

Next, think about testing frequency. Depending on your goals and criticality, you may test your equipment anywhere from annually to hourly. If you think back to our compliance example, annual testing might suffice; however, if your program is based on maximizing the reliable life of an asset, you may consider a continuous monitoring approach.

The value of continuous monitoring is that you decrease the testing interval in order to catch issues well before they compound. Usually this approach looks for dissolved gas (DGA) and occasionally moisture as well. Continuous monitoring also helps you understand how to optimize your asset health on a day-to-day, hour-to-hour basis, directly tying your testing to loading conditions, ambient temperatures, production conditions and more. You simply don't have that granular level of detail with an annual sampling program.

However, even with real-time monitoring, you may want to perform a full suite of additional tests on an annual basis to determine how quickly the liquid insulation is aging and therefore how quickly the solid insulation is deteriorating. Tests such as moisture, liquid power and acid all play major roles in the breakdown of the solid insulation, and an online dissolved gas monitor is going to have almost no insight into those realms (unless the condition quickly leads to an active event).

In practice, the more robust strategy involves placing a DGA monitor on a unit with readings every 12 or 24 hours, paired with an annual oil sample including a Liquid Screen, Karl Fischer Moisture Test, Liquid Power Factor, Dissolved Metals (or ICP), Oxidation Inhibitor, Furanic Compounds and Dissolved Gas Analysis. This increases the availability of data from a single data point annually to potentially 730 annually. More data leads to more insight if you have the right tools. Just bear in mind that without the right tools, it often results in chaos and confusion.

Once you identify your testing plan, you can select a laboratory. Be sure to identify which test methods they use – preferably the Standard ASTM test

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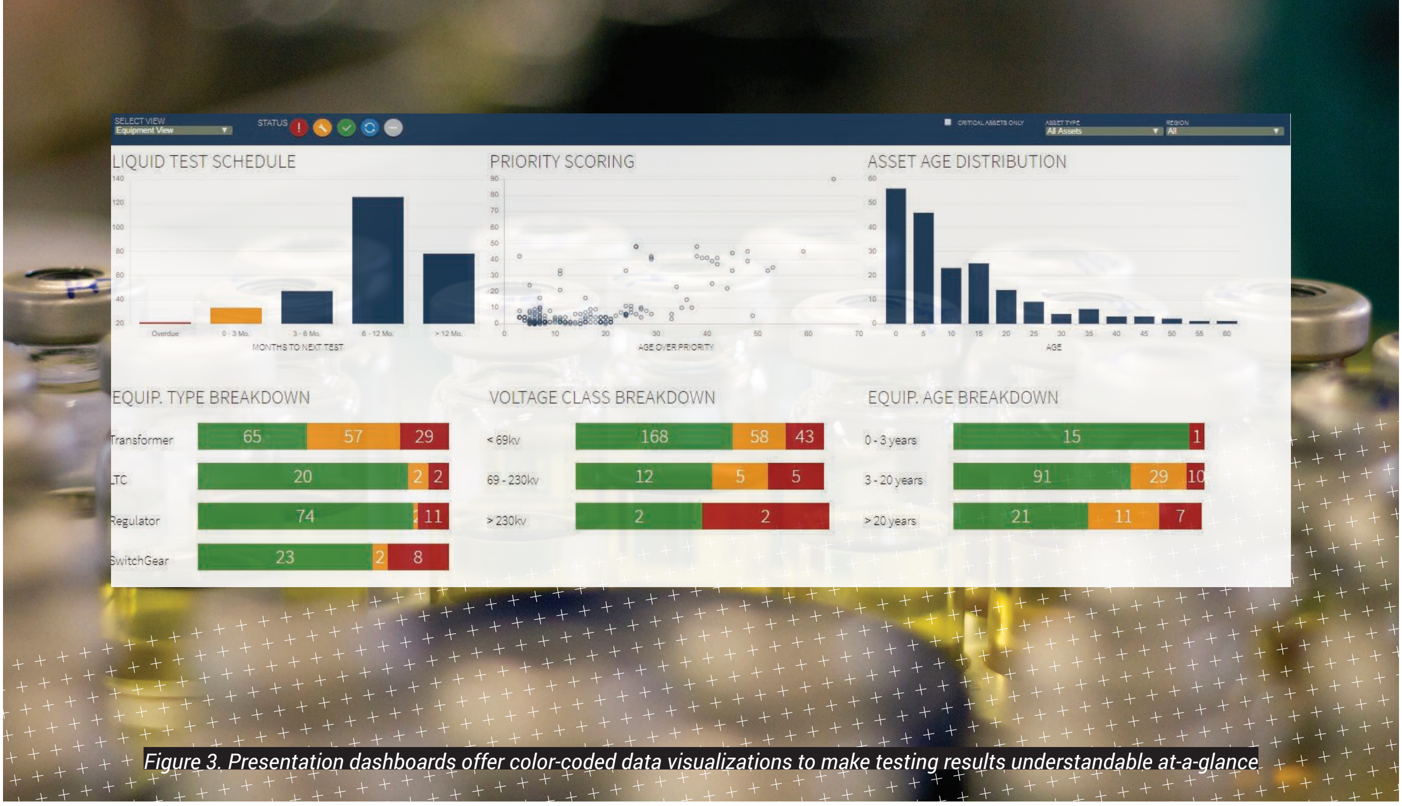

Figure 3. Presentation dashboards offer color-coded data visualizations to make testing results understandable at-a-glance.

methods as referenced by IEEE. It's also smart to evaluate the credentials and certifications of the laboratory. Most testing labs carry ISO 17025:9001 certifications that ensure a commitment to quality, objectivity and standardization.

Analysis and Presentation: Get the Right Information Quickly

You've completed fluid tests… now what? To keep in line with your goals, you must determine what to do with your test results. Are you going to use the IEEE limits, parameters recommended by your testing lab or your own limits on the data? You can also utilize machine learning algorithms that link test results to failure probability. All of these are viable options. Here are just a few distinctions:

IEEE – IEEE limits are tried and true guidelines relating to the safe operation of electrical assets. They group test values into four conditions ranking from normal operating condition to serious active fault condition. More importantly, however, is understanding the framework behind these limits. IEEE limits are built around the serviceability of the liquid insulation. In laymen's terms that means, you are testing the oil to see if it can still perform its primary functions: dielectric insulation, heat transfer, diagnostic. When testing the liquid, IEEE is only concerned with whether the fluid can provide these three functions.

Provider limits – Your testing lab may implement its own limits to reflect the criteria it values. For example, a well-known North American transformer maintenance and testing provider, proliferated an approach called "MaxLife," which aims at maximizing the reliable life of the asset (Figure 2). The difference between this approach and IEEE is that Maxlife focuses more on the solid insulation than the liquid, with the thought process being that if the liquid insulation cannot perform its function, the solid insulation has already been damaged irreversibly. This more holistic approach aims more conservatively at catching and eliminating threats.

Custom limits – If you have specific equipment purchased from the same manufacturer, you have been tracking test results for years, and you have experienced a few failures, you may be interested in setting custom limits. This requires that your team has done the analysis before and understands that certain gas profiles, acid levels or moisture percentages indicate unreliable equipment. You can use software to help customize those limits for your testing program to ensure that any time test results hit your pre-determined limits, you get a notification. This solution is best for teams who have engineering staff on hand and frequently use data analytics.

Machine learning and AI – Machine learning and AI algorithms can find anomalies or trends that lead to

Photo: On Now Digital

Figure 4. Oil samples prepared for DGA test

unreliable assets. The trouble here is the most effective AI systems have neural networks that work best if trained to fixed outcomes using supervised learning – meaning, you need to have failure data available so the system can look back and see what conditions previously led to failure. That's how AI detects anomalies that a diagnostics technician may miss. The cool part here is that, depending what system you are using, the algorithms constantly learn as the system gathers more information. An AI system coupled with a real-time DGA gas monitor would be your most powerful early detection tool.

Once the fluid analysis is complete, there are different methods for viewing your testing data.

You can print paper reports and cross reference them with your analysis, but please note that this method is incredibly time-consuming and leaves a wide margin of error. Similarly, you can use an Excel file provided by your testing company, which at least puts your data in a digital format. However, spreadsheets still require additional legwork in terms of viewing limits. You may want to consider a dashboard or software system that allows you to aggregate your data to your preferred method. These systems do the analysis automatically, and hopefully present you with a clear picture of which assets require your attention first.

A presentation mechanism may not seem important, but in practice, whatever system you use can be the lynchpin for success. How the information is presented to you has a direct impact to your ability to make wise decisions with the data. When considering a dashboard, look for options with visually presented data, clear priority lists, and easy-to-understand graphs (Figure 3). This allows you to quickly make decisions using your testing data to contribute to your predetermined goals.

Game Plan: Create Clear, Sustainable Action Items

Whatever system you use should lead to some type of action step. This should be based upon two primary factors:

- The equipment's criticality within your system
- The condition of the asset

Ideally, you would have enough time and money to fix every issue every time. However, in the real world, you have to prioritize your maintenance staff and dollars to fix your most crucial piece of equipment first. Then prioritize the rest of equipment accordingly. These decisions should reflect both your previously performed criticality assessment and your top-level goals. Your engineering staff, or a qualified engineering contractor, can assist you in crafting your action plan.

Like every good action plan, you need a feedback loop. Implement a process whereby you follow up with your equipment through visual inspection or verification of the work or testing done. Usually this can take place during your next testing cycle, but it remains a best practice to review any work done as quickly after completion as possible. This includes anything from inspecting the asset for proper reassembly to re-testing for improved results to rating the accuracy of the analysis system or contractors you employed in the process. Anything uncovered here should be included as an improvement in the next annual testing and maintenance cycle. This system enables continuous refinement as organizational goals change.

Sounds Great!
But How Does It Really Work?
Understanding and executing a plan are often two very different things. Here are a few practical examples that may help make this process achievable. These sample plans show the types of goals you can tie to fluid testing and the steps you should take to begin addressing them. Please note that these are examples only. In all cases, the appropriate test recommendations will vary by fluid and equipment type.

Conclusion

Whether you are a large organization or a small startup, a proper testing and maintenance plan is key to a reliable electric system. How you accomplish that is up to you, but there are tools available to simplify the process, streamline the data and execute a strategic vision in light of your organization's goals. The tools are numerous, and the challenge is large, but with the right direction, you can be the hero every organization needs.

Example 1:

I aim to decrease capital expenditure for a better return on assets.

Goals:
- Decrease capital expense
- Extend current asset life
- Eliminate unplanned downtime

Plan:
- Complete fluid testing bi-annually
- Conduct the following tests:
  - Liquid Screen (Acid, IFT, D1816, Color, Specific Gravity, Visual, Sediment)
  - Karl Fischer Moisture Titration
  - Liquid Power Factor
  - Oxidation Inhibitor Content
  - Dissolved Gas Analysis (Figure 4)
  - Dissolved Metals (ICP)
  - Furanic Compounds
  - PCB
- Use MaxLife parameters to evaluate the data
- Complete criticality assessment of equipment
- Pro-actively service five most critical maintenance items
- Acquire feedback from all involved parties

Example 2:

I aim to increase the reliability of my equipment by optimizing my system.

Goals:
- Increase condition visibility
- Utilize best in class tools
- Eliminate unplanned downtime

Plan:
- Complete criticality assessment of equipment
- Commission online dissolved gas monitors on all critical equipment, sampling in 8-hour intervals
- Limit fluid sampling to an annual basis
- Conduct the following tests:
  - Liquid Screen (Acid, IFT, D1816, Color, Specific Gravity, Visual, Sediment)
  - Karl Fischer Moisture Titration
  - Liquid Power Factor
  - Oxidation Inhibitor Content
  - Dissolved Gas Analysis
  - Dissolved Metals (ICP)
  - Furanic Compounds
  - PCB
- Use AI algorithms to analyze data for anomaly detection and pre-failure warning via a dashboard
- Pro-actively service five most critical maintenance items
- Acquire feedback from all involved parties

Example 3:

I aim to stay compliant with my testing program.

Goals:
- Remain in compliance
- Limit expense

Plan:
- Complete fluid testing annually
- Complete the following tests:
  - Liquid Screen (Acid, IFT, D1816, Color, Specific Gravity, Visual, Sediment)
  - Karl Fischer Moisture Titration
  - Liquid Power Factor
  - Dissolved Gas Analysis
- Use IEEE parameters to evaluate the data
- Acquire feedback from all involved parties