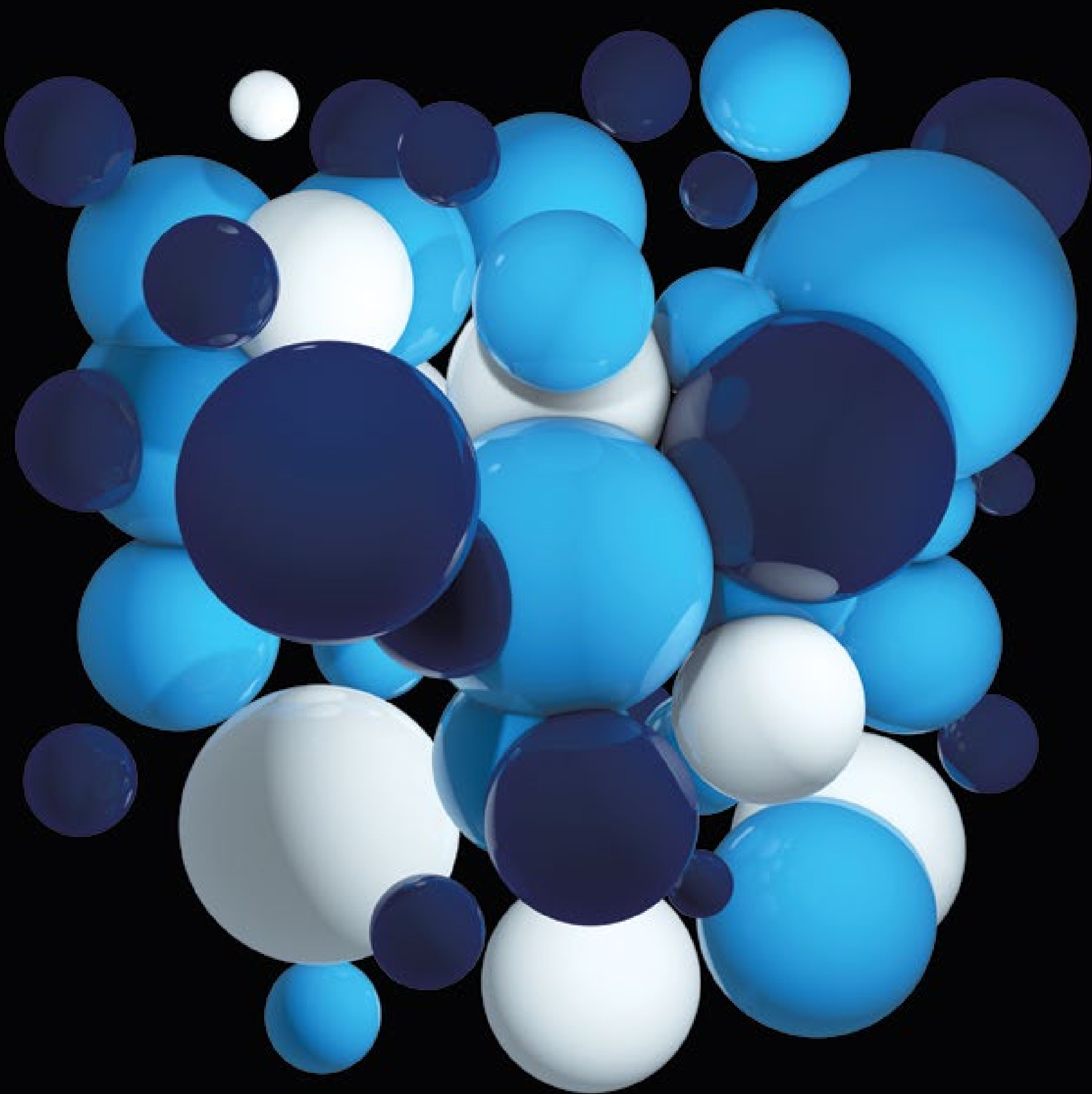
COLUMN

DGA monitor accuracy – Data and decisions



ABSTRACT

This article explores the intricacies of DGA monitor accuracy, emphasising the challenges in extracting dissolved gases from transformer oil. Despite international standards like IEC 60567 recommending a maximum accuracy of 15% for complete DGA systems, real-world application, as reflected in CIGRE brochures, suggests a potential deviation closer to 50%. The implications of varying accuracies on diagnoses, particularly when employing diagnostic tools like the Duval triangle, are analysed.

KEYWORDS:

DGA, DGA monitor, Accuracy, Extraction method, CIGRE, Diagnoses, Duval triangle

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Introduction

So, your DGA monitor has an accuracy of 8%: what does that mean? Getting the dissolved gases out of the oil is not a simple process. It has a lot of variables involved, and its accuracy will depend on the extraction method, gas handling, the sensing system, and the oil itself [1]. What accuracy can we expect? IEC 60567 gives 15% as a maximum for a complete DGA system, including both gas extraction and analyses [2]. CIGRE has some excellent technical brochures relating to monitor accuracy, which show that some DGA monitors may have an average accuracy closer to 50% than the more expected 15% when in the field making real measurements with oil [2]. Consequently, we should always be looking for *system* accuracy – including gas extraction, handling, and analyses – for calibrated measurements of gases in oil, in the field and in practical applications. After all, we will be using the data generated to make diagnoses on real transformers in the real world.

But what does an accuracy of 8% mean? Accuracy should tell us how close we are to the "real" value. Suppose we supply a set of "standard" oil samples, each with 100 ppm of a particular dissolved gas, and have the DGA monitor measure that gas in each sample. Then, if a monitor accuracy is quoted at 8%, then *most* monitor results should lie between 92 ppm and 108 ppm. There's no guarantee that *any* individual result will definitely fall within the 92-108 ppm range, but the majority should.

We should note that some monitors provide a composite gas value, where a combined value represents proportions of some of the gases present, say add 100% of hydrogen, 20% of carbon monoxide and so on, but the final value cannot be worked back to individual gas levels. Such devices are useful detectors of a possible rise in gas levels but do not provide any diagnostic value and are not considered in this article.

The interpretation of DGA results

The interpretation of DGA results may be difficult as there are several guides and standards which can assist but may provide different diagnoses, limits, or trend values [3]. However, the accuracy of individual results means that we may have several diagnoses to choose from within a particular method [4]. The Duval triangles and pentagons are a common and effective tool for aiding in diagnosis; we will use one of the triangles to illustrate the impacts of poor DGA accuracy, noting that this is not a criticism of the triangles but a simple way to give a visual display of the impact of accuracy on diagnoses, and thus on the resulting decisions and actions.

If we have one result from a DGA monitor, we can plot that on, for example, the Duval triangle in Figure 1; sections of the triangle are labelled with different diagnoses (D1, T1, etc.), and an individual measurement result is plotted as a single point [5]. For this individual result, the diagnosis is D1, or "low energy discharge (sparking)".

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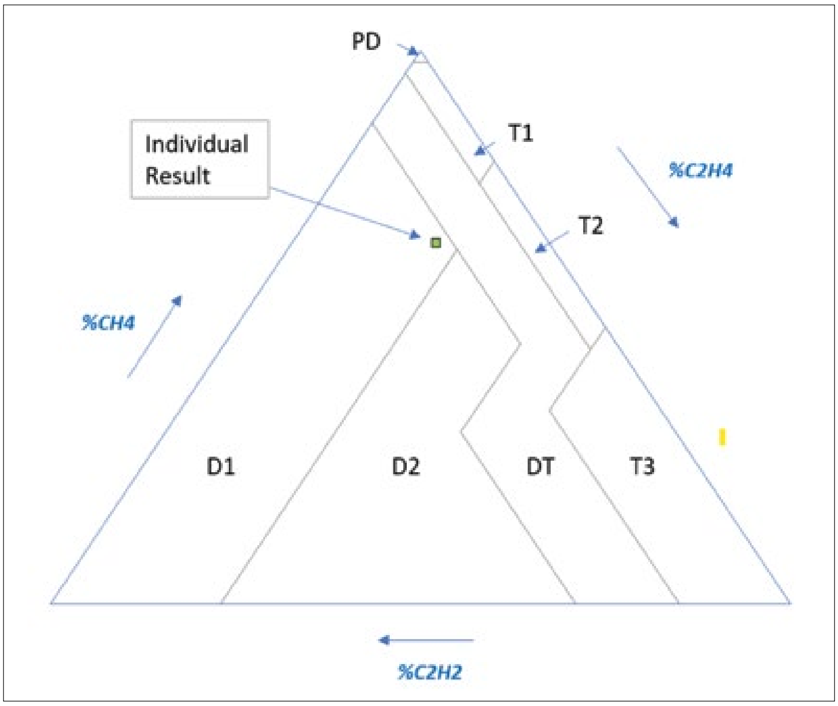

Figure 1. Single DGA measurement plotted on a Duval triangle

If we were to estimate the monitor accuracy at 15%, we can use the individual point we have to generate multiple possible "true" results, each of which could generate the individual value we have

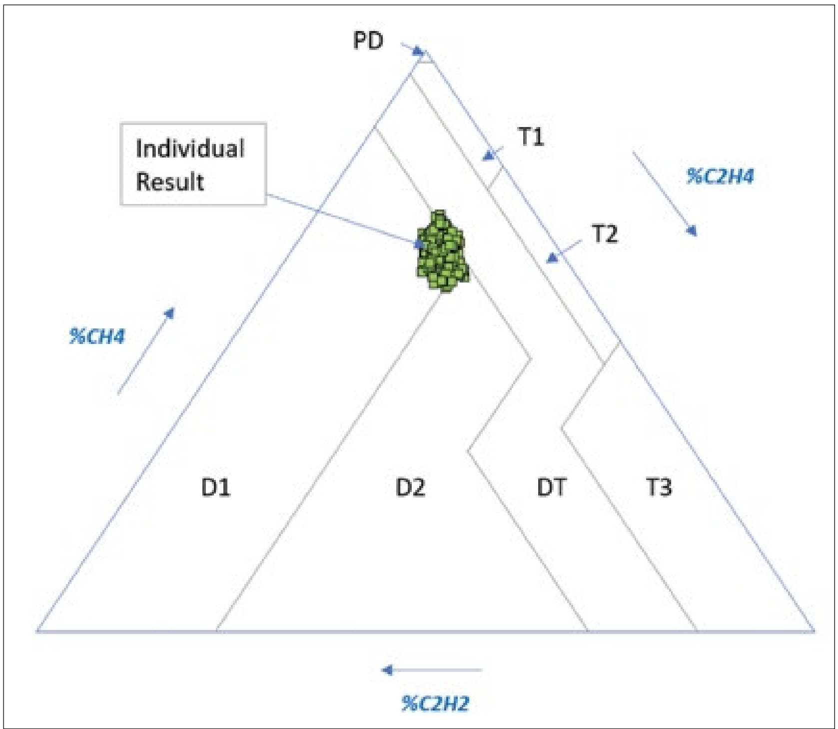

Figure 2. Cloud of possible results at 15% accuracy

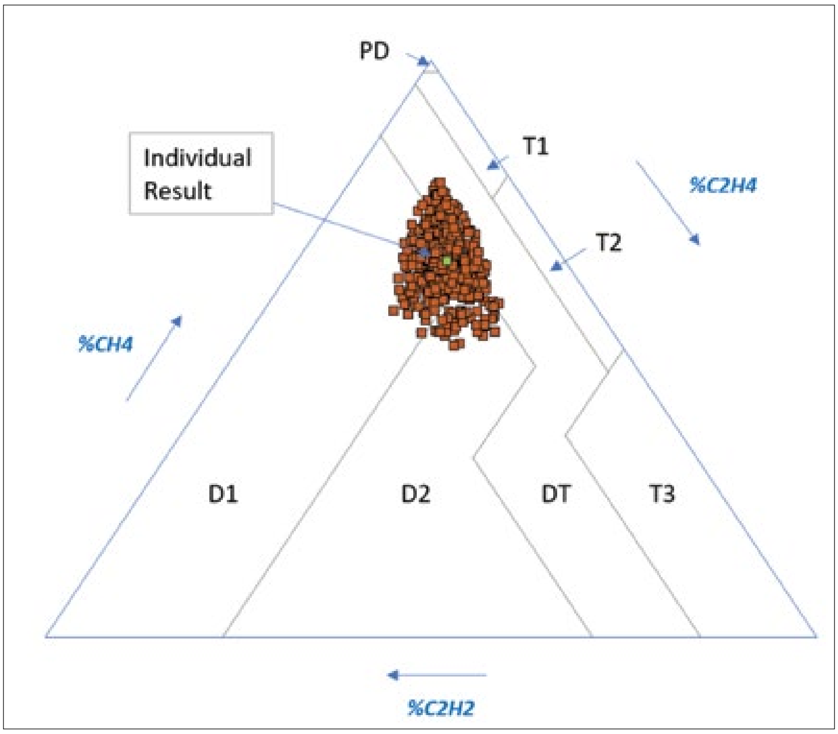

Figure 3. Spread of possible true DGA values for a single measured value for a DGA monitor with +/- 35% accuracy

"true" results, each of which could generate the individual value we have. Box 1 goes through the math, allowing us to take that individual result and generate many possible versions of the true level in the oil. In Figure 2 we have randomly generated many such "true" values, each of which is within the accuracy required to generate the individual result we have.

Having good repeatability may give more credibility, but it may also reflect a consistent, systematic error

Any one of the points plotted in Figure 2 could yield the individual result that we have, which means we have a problem, as the possible true value of gases in oil could also now lie within D2, which is "high energy discharge (arcing)" or within DT which is "mixture of thermal and electrical faults". Which is it? If we only have one result, we might be tempted to think we have a definitive diagnosis. Having good repeatability may give more credibility, but it may also reflect a consistent, systematic error.

In Figure 3, we plotted the results at 35% accuracy, reflecting some of the results from the CIGRE study – the original point hasn't moved, but the cloud is now much more diffuse [3].

In field trials discussed in the CIGRE report, a number of commercial DGA monitors did show accuracies of 35% and worse. We should note that 35% or more are accuracies seen in practice for combined gas extraction and sensing in the real world, not accuracies of the gas sensor alone during calibration. Consequently, for some DGA devices, Figure 3 represents the accuracy we would expect, with the consequent variability in diagnoses.

Finally, in Figure 4, we show three levels of accuracy:

- 5%, in green, which is the best laboratory grade and may be achieved in the field by gas chromatograph-based devices with appropriate gas extraction and gas handling

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- 15%, in yellow, for reference, as it is achieved by most laboratories
- 35%, in red, as may be provided by less accurate monitoring devices in practice in the field

The conclusion is that the diagnosis may be very unclear for less accurate devices, and a sample should be taken manually for laboratory diagnosis. But taking a sample is also a risk – as per the case discussed at Doble's "Life of a Transformer" seminar in 2020, where a monitor indicated a problem and the transformer failed while samples were being taken [6]. In cases where a severe issue that presents a risk to the engineer is suspected, remote sampling or sampling whilst de-energised should be employed.

It is also worth noting that the lines demarcating different zones on a Duval triangle are also subject to accuracy considerations! The boundaries are exact in the charts but have their own levels of precision based on diagnoses from oil samples, which have their own inherent variability, meaning that the lines themselves are subject to accuracy considerations.

We could hope to use trending to overcome some of the effects of poor accuracy, but that can lead to its own problems. In Figure 5 we show just one key gas, ethane, from measurements taken every two hours with a multigas DGA monitor, with the final three points showing a significant rising trend. Other gases acted similarly, and the question was asked: is the variability in results due to the system accuracy, or is this truly a rising trend?

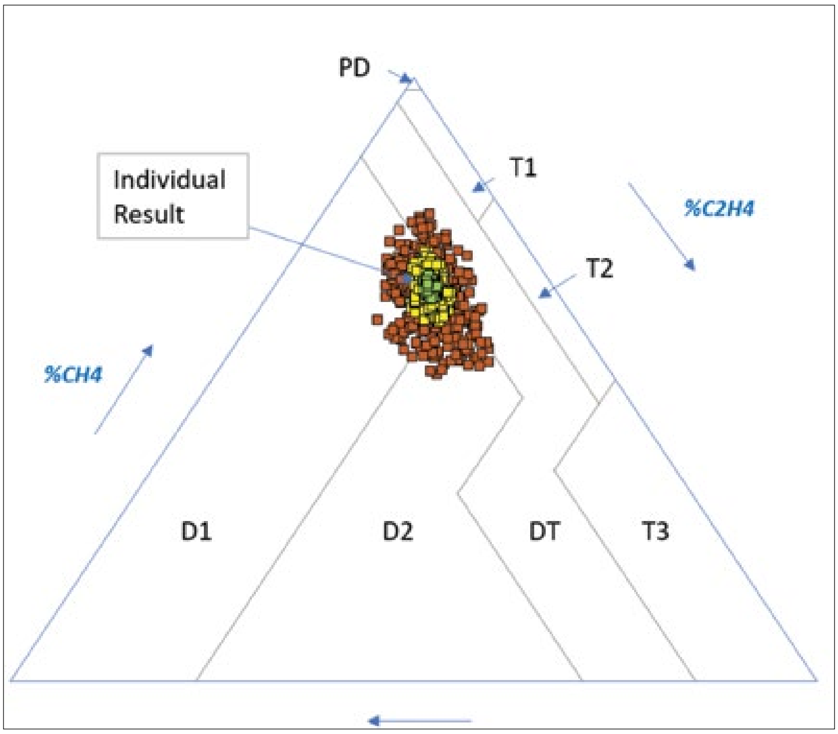

Figure 4. Three levels of accuracy

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In fact, the data in Figure 5 reflects the "natural" variation in the system and is nothing to worry about, but it could, just as easily, have been the start of something bad.

Conclusions

We must make sure we have the accuracy of the DGA monitor *system* as a whole, ***in practice***, not just the sensor during calibration or verification. Making measurements in the field with what may be old transformer oil is challenging, and we need to consider not only what the accuracy is when the monitor is in use but also what the implications are for diagnoses. Better accuracy in the monitor as a system makes for better decisions in the end.

We have used a Duval triangle as an illustration of how variability in accuracy can lead to variability in diagnoses – this is not a complaint about the Duval triangles, which are an excellent tool for diagnostics when used appropriately, and similar effects can be seen in many of the available diagnostic tools.

Acknowledgements

I would like to thank Mohamed Khalil and Andy Davies for their insightful and clarifying comments on this article.

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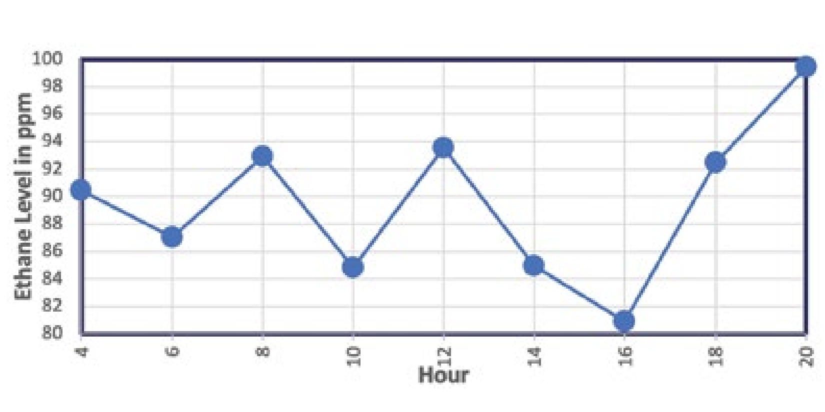


Figure 5. Variability in monitored value for one key gas

Some math will allow us to run a simulation with a lot of measurements:

- Let L ppm be the actual level of a particular dissolved gas in oil: something we would set up in a laboratory-made sample, or which we would like to know from a field sample

- Let M ppm be the measured value we have from our monitor, which we do know, along with the monitor accuracy, A

- The accuracy of an individual result should be within A% of the value of L, but we do not know where within that range any one result lies

We can then estimate some limits and say an individual result will be between:

- lower limit $L_{min} = L - (L * A/100) = L * (1 - A/100) = L * (100 - A)/100$

- upper limit $L_{max} = L + (L * A/100) = L * (1 + A/100) = L * (100 + A)/100$

So, if we know the individual result, M, we can work back and show that we can calculate a range of what L might have been:

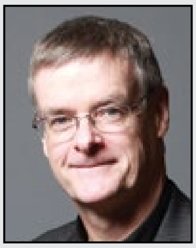
$L_{min} = M \times 100/(100 + A)$ and $L_{max} = M * 100/(100 - A)$

Given L, M and A, generate a random value, V, for the accuracy of an individual sample in the range $-A \leq V \leq A$ and, thus, for this particular measurement, the actual level L can be calculated from:

$L = M * 100/(100 + V)$

We can, therefore, generate many possible values for L by randomly generating values for V and running the small calculation.

Author



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