



ABSTRACT

In the last two columns, we have summarized the advantages of performing DGA and insulating oil tests in a local lab attached to the same organization as the transformer owner and outsourcing insulating oil tests as well as many other testing services in the energy segment. Some of the advantages of an internal oil lab are preserving the data, avoiding cyber-attacks and critical data leakage to hostile organizations, and the benefits of preserving knowledge and experience.

In favour of outsourcing, laboratories have a huge difference in prices, and increased test accuracy has the advantage of much larger experience accumulated in specialized outsourced laboratories. In our time, most transformers are tested in external laboratories. Although online devices may also be seen considered an external outsourced lab, even if they are physically located in the vicinity of the transformer, this column will not cover them. This column will try to illuminate the most important issues to be considered in selecting the most suitable

outsourcing laboratory for the client's needs and, from the aspect of laboratories, how to attract more clients.

Having the chance to be on the other side of the fence, I know the main concerns of transformer users, laboratory managers and financial staff for these oil tests. The column will describe the main points for each discipline.

KEYWORDS:

DGA, diagnostics, outsourcing, selection, transformers oil

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Where to perform the dissolved gas analysis? - Part III

1. Introduction

Oil tests are a very important tool in preserving the smooth operation of transformers and machines. Additionally, performing tests on most types of oil requires expensive devices and educated and experienced staff, which can generate high expenses. Many organizations around the world find that sending their oil tests to an external outsourced laboratory is far more rentable and adequate. As emphasized in the last column, the consideration of insulating oil tests is different from other oil tests and other chemicals. In insulating oil tests, for example, reacting time and accuracy at a low level and high concentration is crucial.

Transformer owners need to be able to obtain reliable oil tests from solid and reliable laboratories. Those tests are to be circulated at certain periods, from once per year to once per three months, but also at emergencies. Another important point is the ability to maintain a single database of all oil tests, with the history of all tests synchronized and made with a similar methodology, even if the laboratory was switched for financial or other reasons. One of the great obstacles for this mission is the nonuniformity of most oil test

methods, especially DGA. Another issue in this domain is the lack of certified materials with measured and verified values.

Commercial laboratories surely tend to have more clients and process more samples. However, there are a couple of constraints for liquid oil tests. The oil that arrived in the lab should be tested within a maximum of one week to allow time for a retest if necessary, to write reports, and to be approved by a chemical expert. On the other hand, taking oil tests normally requires time, and DGA may be completed in 24 hours. Other oil tests need even three full days, net. Another important restriction is a specific order that must be kept in performing these tests, as some tests, such as DGA and water, must be performed before others because of acidity or dissipation factor.

2. Considerations in selecting the supplier of insulating oil tests for users

1. ASTM vs IEC. The tender for the selection of a laboratory should be done among those providers who use the same standard methods for the equip-



Disclaimer: Because of the sensibility of commercial issues and to preserve neutrality, no specific company of actual DGA providers will be mentioned in this column. I will only use general continent identifications, mainly because different countries have different test policies. Of course, this column will not recommend using any internal or external DGA service provider. Each case should be customized according to specific needs.

Table 1. Dissimilarities between the two main standard methods of DGA

DGA method	Calculation	IEC 60567	ASTM D3612	Compatibility & remarks
Vacuum extraction by partial degassing	Ostwald coefficient gas in oil and gas peaks calibrated by gas in gas	7.3	A	Yes Suitable for factory test
Stripping extraction method	Efficiency coefficients and gas peaks calibrated by gas in gas	7.4	B	Yes Not suitable for factory test
Multi-cycle vacuum extraction using Toepler pump apparatus	Absolute volume of gases and gas in gas calibration	7.2	No	Best and absolute method
Headspace method	IEC calibrated by gas in oil standards or special partition factor ASTM by special coefficients and gas peaks calibrated by gas in gas	7.5	C	In most cases, NO Not suitable for a factory test

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ment and oil. The standardization world is divided into two parts: the USA and parts of the world influenced by the USA, that use ASTM, and other parts of the world that use IEC methodology. Most oil tests are indeed different from ASTM and IEC standards

(see Table 1). DGA is also quite different from all other methods, together with partial vacuum extraction with or without mercury. Of course, the most popular DGA method is the headspace method. The industry is under the impression that by using commercial gas-

in-oil mixtures, the difference may be overcome. This is incorrect because the commercial gas-in-oil mixtures do not provide calibrated values, especially that of oxygen and nitrogen, which are the most problematic gases to be measured by the most popular DGA method – headspace.

2. For **performance tests**, the user needs to ask the laboratory to provide the last two proficiency tests, either by two commercial organizations that arrange such tests: ASTM and IIS. Any other proficiency tests with more than five different laboratories are also acceptable.

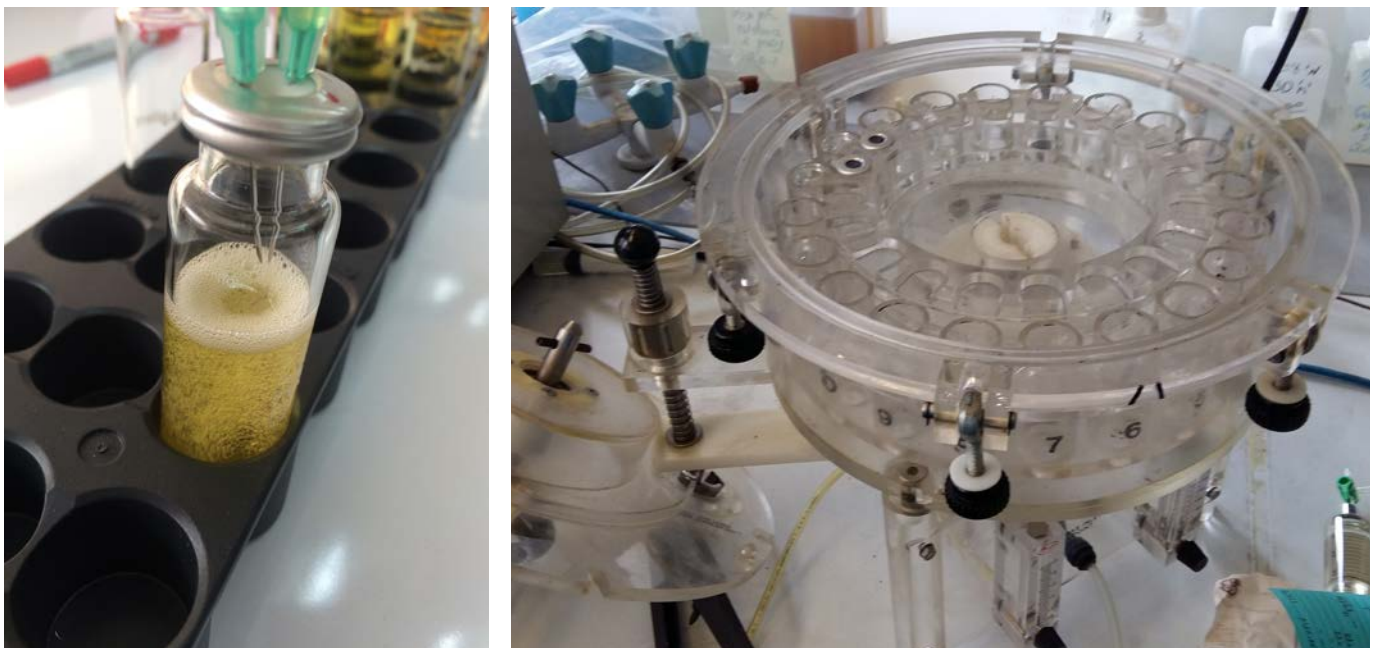


Figure 1. DGA headspace vial filling by ASTM procedure and IEC procedure – each method affects measured values, especially oxygen and nitrogen

The laboratory clients are entitled to ask and observe the proficiency tests along with the performances, and accreditation itself is not an assurance of adequate and continuously accurate tests

- 3. **ISO 17025 is not sufficient.** If a laboratory holds an ISO 17025 accreditation, it is not enough. The laboratory clients are entitled to ask and observe the proficiency tests along with the performances. Accreditation itself is not an assurance of adequate and continuously accurate tests.
- 4. **Blind tests.** The user should send at least two oils to a potential oil test supplier, as well as to a well-known and accurate laboratory. The user can also send a prepared or commercial gas-in-oil mixture without specifying

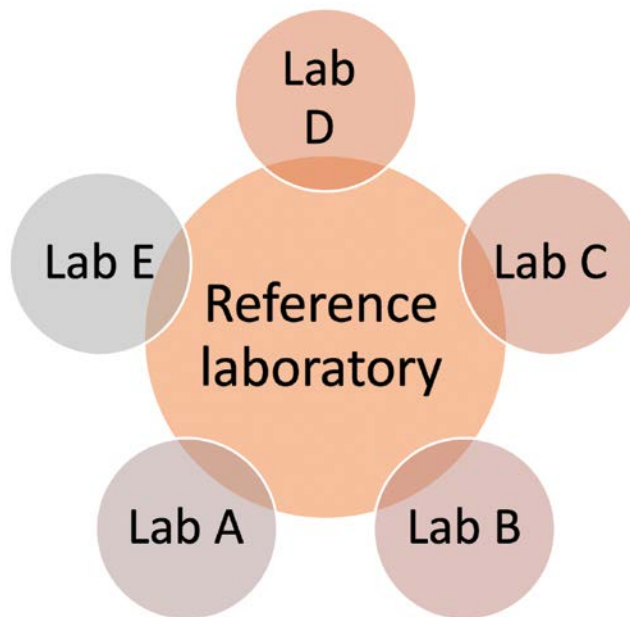


Figure 2. Proficiency tests among five laboratories organized and conducted by a reference laboratory – the results have been returned to the central lab and compared

the concentration, of course. Those samples should be sent as routine oil tests. This step is necessary because almost all participating laboratories that perform or organize proficiency tests treat the samples intended for such special tests with extra care,

meaning the tests are performed only by the most experienced and qualified chemists and supervised as special samples. The time and effort put into the samples intended for round-robin tests are usually double that in the case of usual routine tests.



Figure 3. Blind tests increase the reliability of results

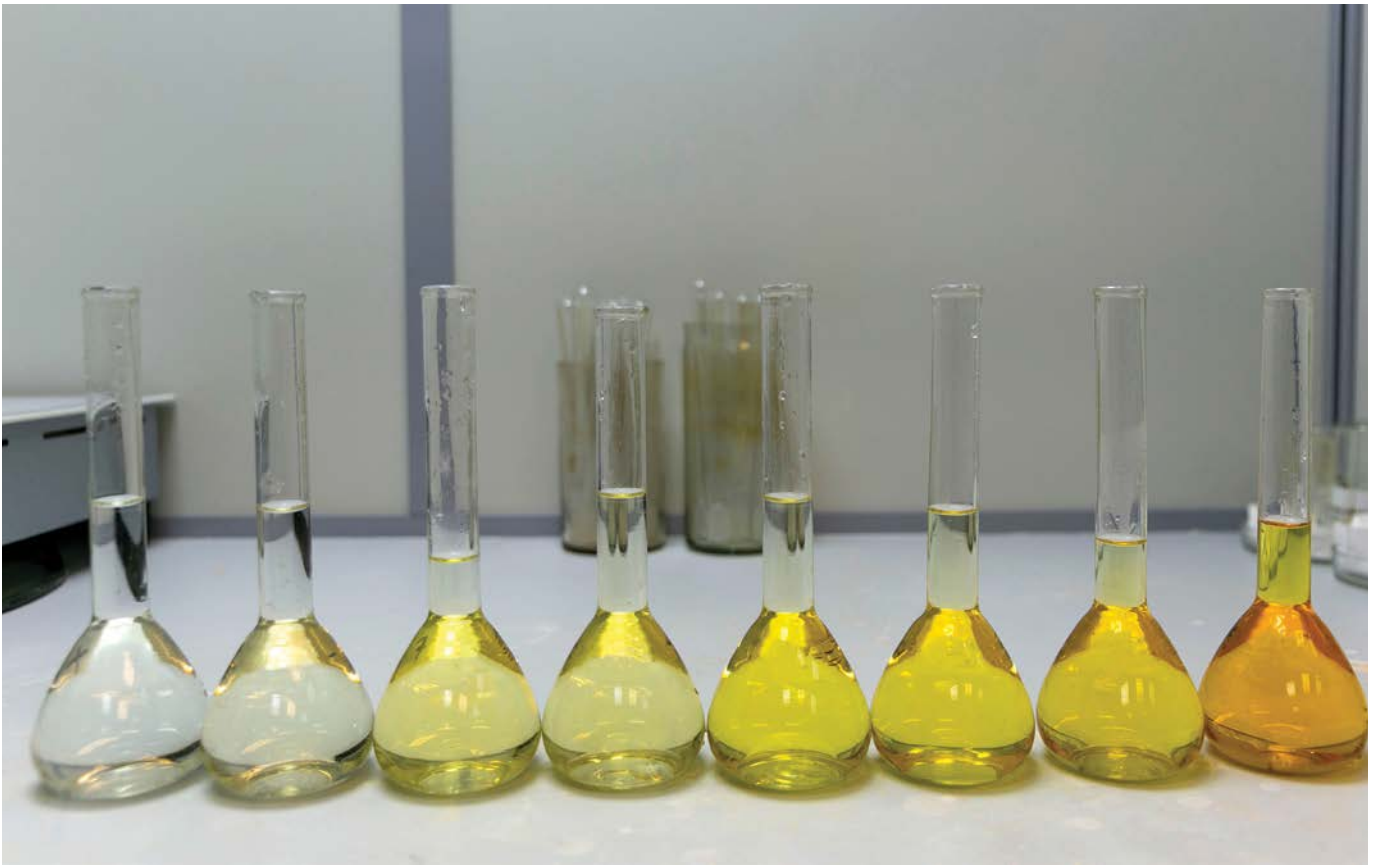


Figure 4. Materials for the calibration curve

If the samples are not delivered within the acceptable time, they may deteriorate and become inadequate for testing

5. Switching laboratories and synchronizing slopes. For being able to switch between laboratories according to their price and conditions, it is recommended to obtain at

least three different results for each parameter to build adequate calibration graphs and compare the slope of those graphs between the laboratories.

6. Potential visits. The users should demand the option to visit and control the test procedures by themselves or through a neutral specialist. This type of optional control will increase the care of the lab for this specific user.

7. Timing. Normally, the number of oil tests are specified in a tender, as well as their frequency and approximate timing. The users are also obliged to stick to the requirements because the laboratory allocates the time slot and effort

Table 2. Comparison of the gas calibration slopes with laboratories that are candidates for tenders

Slopes of inhouse DGA gas in oil concentration			Accredited external laboratory
	High concentration range	Low-medium concentration range	
Hydrogen	0.36	0.41	0.54
Methane	0.9	0.95	0.89
Ethylene	0.76	0.77	0.85
Ethane	0.84	0.92	0.81
Acetylene	0.77	0.75	0.85
CO	0.89	0.89	0.89
CO ₂	1.3 + 76	0.92 + 96	1.0 + 1.6

to fulfil those requirements. If the samples do not arrive within the acceptable time, they may be inadequate due to the time elapsed between the arrival and testing. In this context, it is important to avoid taking samples and sending them to laboratories before the long holidays. Also, the summer vacation period and electrical peaks are problematic for routine tests.

- 8. Transport.** Selecting the most suitable delivery company to the destination country is of the utmost importance. In our post-Covid time, some delivery companies have disappeared, and others have real difficulties operating in specific regions. It is recommended for both the user and laboratory to be familiar with the most efficient delivery company between the countries of origin and destination. If the company is not well selected, the precious oil sample will travel to many transit centres, and there will be an increased chance of it being retained at customs longer than necessary or being damaged due to multiple flights. Oil samples should arrive from the user to the lab within a maximum of four working days to preserve the gases in syringes, for example.
- 9. Price.** The price of oil tests should be considered, particularly for a single test such as DGA or in total, if all routine oil tests are required. The user should take into account the price of the customs release and any additional costs. Also, users should declare the cost of the oil and vessel, but authorities from different countries may charge different fees. It is recommended to declare it as “for test purposes only”.
- 10. Oils to the USA.** Users sending tests to the USA should be aware of their PCB content. The US authorities demand a declaration that oils entering the USA are PCB-free. Of course, no

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Selecting the most suitable delivery company for delivering the oil samples to the destination country where the lab is located is of the utmost importance



Figure 5. A bubble enters the syringe during air transportation



Figure 6. A sealed syringe prepared for air transportation - the sealing between the piston and body prevents leakages

Laboratories that provide all necessary quality data transparently to their clients have a great advantage, since one of the main concerns for users worldwide is data reliability

oil tests entering the USA are verified, but if the user fails on this issue, it may have personal consequences for the users. Some US labs receive their oil samples from abroad through Canada or Mexico.

11. Oil vessel selection. The selection of an oil vessel is important for different purposes:

- The ability of the sampling team to use specific vessel types. If the technicians are used to taking oils in bottles or ampules, they will not be able to obtain proper oil samples with syringes and vice versa.
- **Laboratory testing device.** Some DGA and oil test devices are more suitable for one type of vessel, such as a syringe for DGA headspace and non-plastic containers for water and breakdown voltage. Some users prefer taking oil samples in plastic containers because they are much cheaper and non-breakable.
- **Overall costs.** Special and expensive vessels are transported empty

and clean before or after the sampling, such as syringes. If those belong to the laboratory, they are delivered before the sampling, and if they are the user's property, they must be returned clean to the user. This, of course, imposes additional costs, time and logistics. Using glass bottles, for example, may save the cost of two-way transportation. Metal containers may be transported once as well, depending on the cost.

12. Reports. In addition to the PDF format, users may request the test reports in Excel format to be able to build a numeric database for calculating local limits by the 90 % philosophy.

3. How outsourced laboratories may attract more clients for oil tests

1. Transparency. Laboratories that provide all necessary quality data to their clients have a great advantage. One of the main concerns for users worldwide

is data reliability. The users need reliable results because costly decisions are made based on those results. The laboratory should be able to provide the users with the performance on round-robin tests and complete accreditation data. The laboratory must specify for which tests it is accredited and for which it is not. Of course, if the laboratory is accredited for one or two procedures (usually PCB tests), claiming that it provides quality tests for all oil parameters is incorrect. Unfortunately, a couple of labs worldwide have the habit of doing this.

2. Sampling vessel. The laboratory should provide the exact vessel type requested for its apparatus. Supplying those vessels to the customers is recommended, be it with or without a sampling kit containing most of the consumables and accessories for safe and quality sampling. However, limiting the weight of the sampling kit is also recommended to avoid overly expensive transportation. If glass bottles or particularly glass syringes are used



Figure 7. Acceptable vessels for DGA and oil tests



Figure 8. Light carton and sponge to protect syringes during transportation

in sampling, it is necessary to provide a special light wrapping to preserve them.

3. **Visits.** The laboratory should be open to customers' visits and eventual training to promote their competencies and expertise.
4. **Test technicians should be aware of test purposes.** Normally, big laboratories employ chemists specializing in oil and chemical tests. Such chemists and technicians are not usually aware of the tests' meaning and importance. If the laboratory technicians are well-trained also in the importance of oil tests and their consequences in the field, there is a great chance that oil samples will be treated according to their impact in practice. It is preferred that the oil lab is not separated from the "patients", as is the usual case with hospital laboratories.
5. **Diagnosis.** In the past, a few quality labs have limited themselves to providing reliable results, just as a few DGA online devices provide only figures without a diagnosis. It is desirable to focus on providing reliable tests and leave the diagnosis to the users or external DGA experts. The chances are quite low that a remote laboratory in a different country and probably a different continent knows details about the transformer's state and operation regime, and so are the chances that it would provide a reliable diagnosis. For example, the peak time, or even the loading time, is essential for the assessment of the life assessment of a transformer.

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6. **Points 4 and 5 are not in contradiction.**
7. **The malleability of the testing procedure.** The laboratory should be able to provide reliable results by both ASTM and IEC standard approaches. A laboratory located in the USA should offer international and even local clients IEC testing options for all oil test parameters. Equally, laboratories located in Europe should provide ASTM oil tests with the same reliability as for IEC.
8. **Up-to-date technology and knowledge.** Just as in medicine, we like to approach the most educated doctor and participate in relevant conferences and training. The same is valid for the insulating oil test domain, where new materials and technologies are constantly emerging. Transformers are filled with novel types of liquids, the windings are wrapped with new cellulose materials, and the transformer design is dynamic, focusing on loss-reduction, recyclability and, of course, sustainability of materials. Users will also prefer sending their new oil types to experienced and specialized laboratories. Laboratory experts should participate in the relevant working groups of standardization organizations, as well as in focused groups such as the ones in CIGRE. All

laboratory staff should participate in relevant training for operating new devices. Laboratories should implement the most efficient and sophisticated devices and manifolds for oil tests.

9. **Data safety.** Laboratories should be able to prove to the users that they take the utmost care in preserving the test data from being hacked or improperly used. Extra care should be taken in trying to build a large database that will be shared in different studies. Anonymisation of oil test results is not simple, for instance, removing transformer serial numbers from the data. Sharing any oil test results should be done only after obtaining explicit approval from the users. Transformer owners should be 100 % confident that their oil test results are revealed only to those who pay for the tests. The users themselves may then share the results with a human or software expert to have the transformers diagnosed, but then that is the sole responsibility of the users.
10. **Reports.** The laboratory should provide results in PDF and Excel formats to allow for the creation of a simple database of the test history for any specific equipment. It is preferable to offer the client reports in other languages in addition to English, at least in French,



Outsourcing is a beneficial approach for transformer owners as well as for large laboratories since it uses resources and materials more efficiently

Spanish, Chinese, Arabic and Russian. Users will surely prefer reading reports in their native language.

4. Conclusions

Outsourcing is a beneficial approach for transformer owners as well as for large laboratories. Saving resources and materials is also a sustainable approach. Transformer users prefer modern, well-equipped and well-trained laboratories and affordable prices. Large laboratories also have multiple advantages, as they can get accredited and have a large number of customers from different parts of the world. Having those advantages is important both to users and the lab chemists, so they can freely communicate and be transparent with each other without breaching the data secrecy of the results and laboratory procedures. If the users switch tests between two synchronized and quality laboratories, it will not affect the continuity of the user's database. As explained in the previous column, it is possible to avoid the urgency of testing

with a portable device. Those cases are rare in transformers but frequent in oil treatments. The users need to be trained and aware of potential mistakes that outsourcing insulating oil tests may bring,

while laboratory managers may use fair methods to attract clients to a reliable and transparent organization. Of course, this transparency should include the quality of all transformer data.

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Marius Grisar holds an MSc in Electro-Analytical Chemistry from the Israel Institute of Technology. He has almost 30 years of intense experience in almost all transformer oil test chains, from planning, sampling and diagnosis to recommendations and treatments, mainly in Israel but also in other parts of the world. He is responsible for establishing test strategies and procedures and creating acceptance criteria for insulating liquids and materials based on current standardization and field experience. In addition, he trains and educates electrical staff on insulating matrix issues from a chemical point of view. He is an active member of relevant Working Groups of IEC, CIGRE, and a former member of ASTM. He is also the author and co-author of many papers, CIGRE brochures, and presentations at prestigious international conferences on insulation oil tests, focusing on DGA, analytical chemistry of insulating oil, and advantageous maintenance policy for oil and new transformers.