ABSTRACT

Mineral oils, as well as esters and silicone oils, are precious materials, and their manufacturing processes have a negative impact on the environment and reduce the stock of crude oil in the case of mineral oils or natural resources in the case of esters oils. Also, silicone and all other types of insulating liquids impose stress on the environment and, of course, on the transformer users' budgets.

This article will describe the two main methods that have a tremendous effect on reducing the waste of those important materials and will prove them as true: avoiding oil leakage and synchronizing the oil tests with the procedures. With all those improvements, we could avoid wasting at least 1 million litres of insulating oil annually.

KEYWORDS:

oil, sampling, breakdown voltage, avoiding oil leakages, environment preservation, savings

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Although power transformers are classified as low-tech, their design and construction materials have undergone a revolutionary development when it comes to materials, design and performance

Saving 1 million litres of insulation liquids

Sustainable economics for power transformers

Introduction

Most high-power transformers have been filled with insulating liquids since the beginning of the 20th century. In oil-filled transformers, the real insulating matrix consists of cellulose materials, solid insulation, liquid, and impregnated solid insulation. Although power transformers are classified as low-tech, their design and construction materials have undergone a revolutionary development when it comes to materials, design and performance. Fig. 1 illustrates the dramatic changes in ratio power versus oil volume throughout the years. The new insulating oils are totally different from those manufactured 20 years ago. The constraints put on new compact transformer designs require sophisticated liquids that can isolate better, dissolve more impurities, have an adequate viscosity index for the application and the environment and, of course, have improved oxidation stability. New non-minerals liquids are required to have elevated flashpoint properties, and they have to be stable inside the transformers and biodegradable in the environment. Of course, this is a partial list of all those new properties imposed on hi-tech liquids formulations. In addition to those new products and new stresses, a shortage of classic liquids generates new solutions. As naphthenic primary raw materials diminish, the industry needs to develop new liquids from different prime materials, such as natural gases, or by re-refining used oils. This imposes an economical usage by preserving the existing original oil inside the device. Also, the new non-mineral oil liquid should be preserved due to the much higher cost, specific design, and limited availability.

The aim of this paper is to propose two very easy and applicable methods to economize the valuable and rare liquid inside the transformers. Those approaches are proactive when it comes to both the sustainability and the maintenance costs of the transformers and can even prolong their operational life and help them avoid premature ageing and failures.

Oil tests are beneficial for transformer maintenance, but having too many oil tests is simply too much, especially the most wasteful one, the breakdown voltage test

Excessive and unneeded liquid sampling from power transformers and all other electrical field liquids should be avoided to preserve both the electrical equipment integrity and the environment.

According to Table 1, the most oil-consuming test is the breakdown voltage test. Here is one of the contradictory recommendations for oil test frequencies between CIGRE TB445 and IEC60422 intervals and most of the commercial guides. CIGRE TB 445 brochure recommends oil quality intervals of once every 2 years. DGA intervals are always half shorter, so DGA needs to be tested once per year on most non-critical transformers. On the contrary, private guides recommend performing oil tests once per year (1–2). Of course, oil tests are beneficial for transformer maintenance, but having too many oil tests is simply too much, especially the most wasteful one, the breakdown voltage test.

Table 1. The method of sampling insulating liquids based on IEC 60475. Y = Yes

Sample container	Syringe	Flexible bottle	Bottle	Flexible bottle	Oil volume
Material	Glass	Metal	Glass	Plastic	ml
Oil test					
Dissolved gases	Y	Y	Y		30–50
Water	Y	Y	Y		20
Dielectric dissipation factor (DDF)	Y	Y	Y	Y	200
Particles (not routine)	Y	Y	Y	Y	100
Breakdown voltage (BDV)		Y	Y		1000
Other chemical and physical tests, such as: interfacial tension (IFT), acidity, antioxidant content, color, and appearance		Y	Y	Y	250
All test volumes (ml)					1500

For all modern sealed transformers, testing only water and DGA can be considered, to be conducted using a sample size of up to 50 ml

Table 2. Oil tests intervals: Practice vs CIGRE recommendations

Oil test:	Oil volume	CIGRE TB 445	Regular practice
		Routine	Actual routine
DGA	50	1 y	0.5 y
Oil test quality + furan	1700	2 y	1 y
Total annual consumption in ml per transformer for oil tests		**850**	**1700**
Annual savings in oil consumption when referring to the regular practice of testing frequency		**850**	0
Global savings in insulating oil with respect to the oil testing practice, based on 2 million power transformers		**1,700,000**	0

As may be observed in Fig. 1, oil parameters change quite slowly, so the interval of once every 2 years for major routine oil tests seems to be sufficient.

Due to the reduced rate of oil quantities in relation to power per kVA in power transformers through the years, as seen from Table 3, transformer owners need to consider this parameter when oil sampling is considered.

The withdrawal of oil from certain transformers periodically needs to be restricted to small industrial and transmission transformers. Transformers with a valve as in Fig. 3 have to be tested using a long time interval, or only when it is suspected that they have a problem. Limited sampling should be performed even for large power transformers, which do not have a surplus of oil, as was the case in the past, especially for oil tests that require a large volume. Excessive sampling may cause transformer failures. This is applicable especially to sealed power transformers and the requirements of breakdown voltage oil (BDV) tests. For this type of transformer, it is enough to test BDV once every 5 to 10 years. For all modern sealed transformers, testing only water and DGA can be considered, to be conducted using a sample size of up to 50 ml.

In order to optimize the oil testing process, the recommendation is to use a sensitive thermometer or a relative moisture sensor and obtain the sample when the value of the sensor is stabilized, as in Fig. 2.

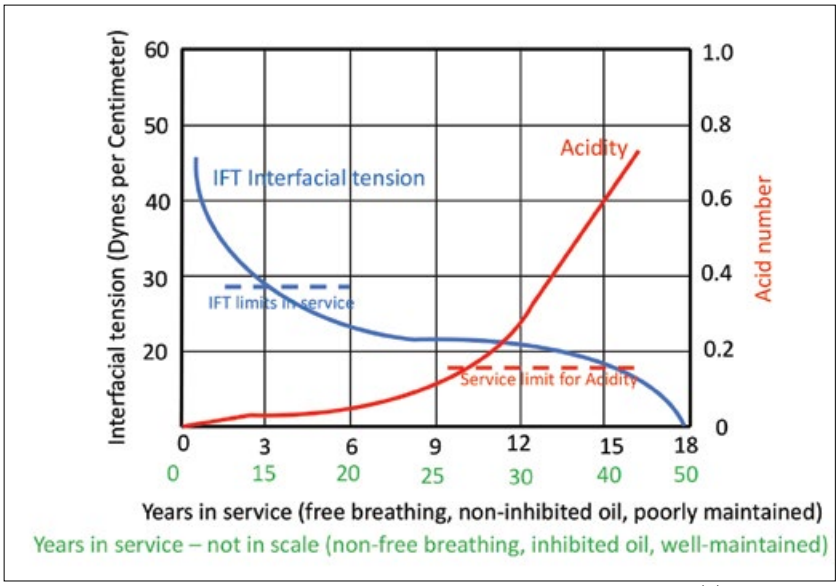
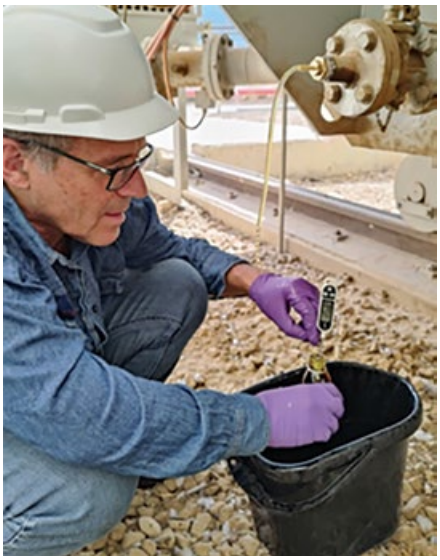


Figure 1. Acidity and interfacial test IFT versus year in service, inspired by (2)

Table 3. Changes in oil quantities per kVA over the years. Based on SDMyers data until 2005.

MVA	Year of manufacture	Liter of oil per kVA
5	1915	7.5
40	1945	2
200	1960	1.2
500	1977	0.5
750	1993	0.4
1000	2005	0.25
1300	2015	0.2
1500	2020	0.15



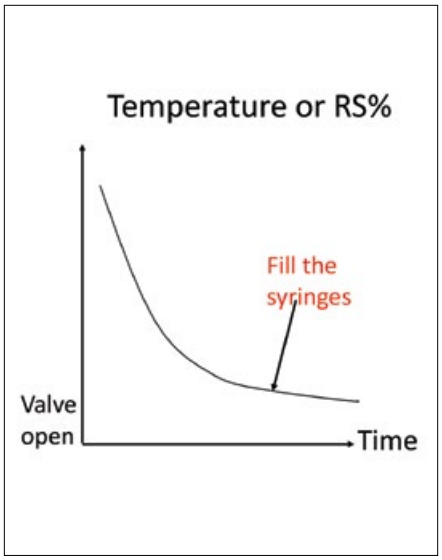


Figure 2. Optimizing the oil sampling process

Figure 3. The recommendation is to only apply long intervals when testing the transformers equipped with this type of valve

Sampling oil from power transformers should be carried out judiciously. Sampling should be carried out using a proper volume and a proper vessel and be synchronized with the measuring procedure, and the transport of the sample to the testing lab should be comfortable for the sampling team. The value of the different tests should also be based on the oil volume that needs to be tested. The higher the sampled oil volume, the more oil will be missing inside the tank, so more weight will need to be transported.

In Table 4, the vessel and oil volume for each test are described.

It is obvious that breakdown voltage tests are the most wasteful oil tests when it comes to the environment. At the lab, all of the oil tests are discarded.

The oil test interval recommended by most commercial laboratories around the world and regular practice is contradictory to the CIGRE TB445 recommendation. Table 2 summarizes their differences.

The volume of oil flushed before sampling will bring at least 50 % higher oil savings. In that case, the real figure for oil saved worldwide may be as high as 2,550,000 litres, if the recommendations from CIGRE TB445 are followed. Those suggestions are very correct, especially for breakdown voltage tests as the most wasteful oil tests. Also, technically, it can be considered that breakdown voltage tests be performed less frequently if water concentration is low in the case of relatively new transformers, where the chance of particles is low.

Currently, there are several attempts in progress to develop online breakdown voltage tests that may replace the need to carry large oil samples from the transformers to the laboratories.

Repairing leaking transformers enables additional substantial oil savings, provides environmental protection,

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Table 4. (Based on Table 1.) Oil tests according to the vessel and oil volume for routine oil tests. Sample containers for oil tests (Y = Yes).

Sample container	Syringe	Flexible bottle	Bottle	Flexible bottle	Oil volume
Material	Glass	Metal	Glass	Plastic	ml
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Particles (not routine)	Y	Y	Y	Y	100
Breakdown voltage BDV		Y	Y		1000
Other chemical and physical tests: Interfacial tension (IFT), acidity (TAN)		Y	Y	Y	250
All test volumes (ml)					1500

and protects the transformer owners' reputation.

Another unpleasant source of oil spilling is leaking. It can occur immediately after energizing due to temperature fluctuation, incompatible sealing materials, and improper design or manufacture. Such events need to be repaired as soon as they appear, so frequent visits and careful inspections need to be performed. When it comes to the new non-mineral oil, these cases are critical for transformer operation as well.

As per report [4], overall, leakage is causing significant amounts of oil waste and the second-highest financial damage worldwide in the last 10 years.

Two leaking transformers are displayed in Fig. 4.

Today, there are very effective technologies available for efficient sealing and avoiding this source of wasting that precious oil and liquid.

Conclusions

It is possible to save at least 1 million liters of insulating oils and liquids annually. By adopting CIGRE TB445 recommendations and, additionally, avoiding oil leakages, transformer owners may preserve both the environment and their precious investment. A million liters annually may have a very positive impact on world economy and the release of more resources for other human needs.

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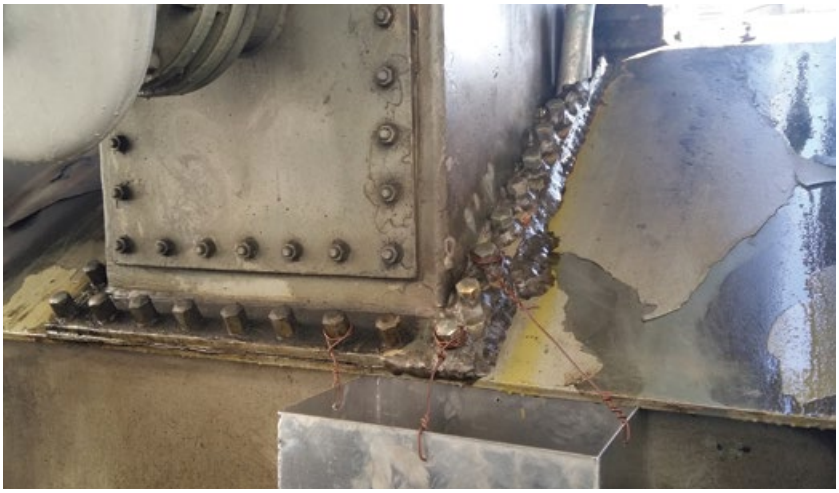

Figure 4. Leaking transformers need to be sealed

A million liters of insulating oil saved annually may have a very positive impact on world economy and the release of more resources for other human needs

Author

Marius Grisaru 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.