Oil sample management (Part 1)

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There are many materials used in the construction of transformers and thus there are many different chemical compounds present, and with heat and oxygen we have a mini chemical reactor. As oil breaks down and reactions take place, the by-products produced are mostly destructive in the long-term and affect the life of the transformer. There are strategies to slow down the pace of these reactions: minimise the heat, minimise the oxygen and minimise the destructive oxidation by products in the process.

A good maintenance practise should be followed to eliminate or slow the ageing process down to an acceptable limit. Within the life blood of the transformer, the insulating oil, there is a wealth of information. This article discusses some of the strategies to ensure the samples are taken correctly and are used to their maximum potential.

The process

In most companies there will be a maintenance strategy in place that will outline the frequency at which a transformer is monitored or sampled. Although oil sampling is only one of the tools that can used to monitor a transformer, it is effective as it is not necessary to de-energise the unit while the sample is taken.

From the maintenance strategy, a sampling frequency will be set, e.g. once yearly. This may only be a minimum requirement. In most companies a computer scheduling system will be used to schedule a transformer unit's samples and other interactive testing or monitoring, and the

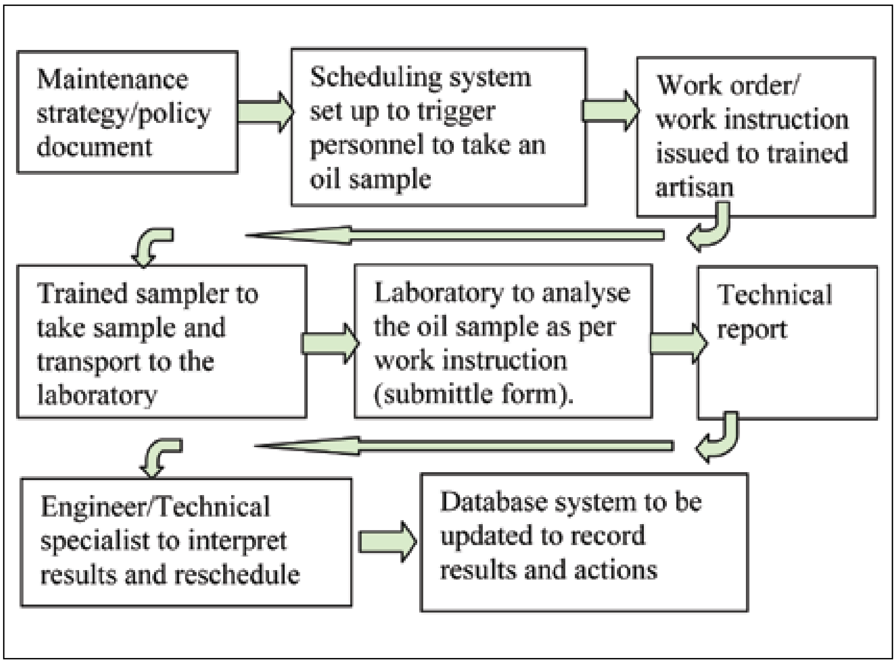


Fig. 1: Sampling process.

Category	Classification	Recommended oil
Class O	Power transformers and reactors with a nominal system voltage > 400 kV.	Inhibited oil (Type I)
Class A	Power transformers and reactors with a nominal system voltage > 132 kV and < 400 kV. Also includes power transformers of any related voltage where continuity of supply is vital and similar equipment for special applications where equipment is required to operate under onerous conditions.	Inhibited oil (Type I)
Class B	Power transformers and reactors with a nominal system voltage > 44 kV and < 132 kV (other than those in class A).	Uninhibited oil (Type U)[5]
Class C	Power transformers and reactors for medium voltage and low-voltage auxiliary, neutral earthing compensators, neutral earthing resistors, earthing resistors and earthing transformers, including diverter tanks of on-load tap changers application, e.g. of nominal system voltages < but excluding 44 kV and traction transformers (other than those in class A).	Uninhibited oil (Type U)
Class D	Instrument, bushing, or protection transformers and oil-filled circuit-breakers with a nominal system voltage > 132 kV.	Uninhibited oil (Type U)
Class E	Instrument, bushing, or protection transformers with a nominal system voltage < 132 kV. Oil-filled circuit-breakers with a nominal system voltage > 44 kV < 132 kV.	Uninhibited oil (Type U)
Class F	Diverter tanks of on-load tap changers, including combined selector/diverter tanks and transformers with a nominal system voltage > 44 kV.	Uninhibited oil (Type U)[5]
Class G	Oil-filled circuit-breakers with a nominal system voltage > 11 kV < 44 kV.	Uninhibited oil (Type U)
Class H	Oil-filled switches, a.c. metal-enclosed switchgear and controlgear with a nominal system voltage < 11 kV.	Uninhibited oil (Type U)

Table 1: Electrical equipment classification.

Note 1: Separated selector tanks of on-load tap changers belong to the same class as the transformer that they are installed on.

Note 2: Oil-impregnated paper bushings and other hermetically sealed units will form part of class D. Inception testing will be performed on these units and thereafter testing will only be performed when these units are out of service. No intrusive testing will be performed on these units.

Note 3: Regardless of the size or voltage of a unit, a risk assessment, or strategic consideration, may justify condition monitoring frequency or analyses requirements of a higher classification.

Note 4: For practical reasons, some owners of electrical equipment can decide that their equipment up to 1 MVA are not included in this classification. Routine monitoring programmes can not be considered economical for this type of equipment.

Note 5: (Type I) or (Type U) classification may need to be altered according to user requirements.

Condition	Class O	Class A	Class B	Class C	Classes D, E, F, G and H
After commissioning/Re commissioning routine tests (Test set 1)	48 h after, 1 week after, 1 month after, 3 months after	48 h after, 1 week after, 1 month after, 3 months after	48 h after, 1 month after, 3 months after	48 h after, 1 month after, 6 months after	Special request
Routine tests (Test set 1)	6 monthly, 6 monthly to yearly	6 monthly to yearly[a]	Yearly[a]	Special request	
Inhibitor (anti oxidant) additive (part of Test set 4)	Prior to filling 6 months after filling and every 2 years	Prior to filling, 6 months after filling and every 2 years	Prior to filling (if stipulated)/ every 2 year/not tested if not present	Not tested	Not tested
Corrosive Sulphur Passivator (part of Test set 4)	1 week after addition 6 months to monitor consumption thereafter every two years (If added)	1 week after addition 6 months to monitor consumption. Thereafter every two years (If added)	1 week after addition 6 months to monitor consumption. Thereafter every two years (If added)	1 week after addition 6 months to monitor consumption. Thereafter every two years (If added)	Not tested
Ageing assessment	Every once a year	Every second year	Dependant on application	Not tested	Not tested
Special investigations (Test set 3)	Special request	Special request	Special request	Special request	Special request
Note: These frequencies refer to a normal routine test programme and if any of the properties indicate significant deterioration, these periods should be shortened accordingly.					
Note: [a] For practical reasons, some owners of electrical equipment may decide that their equipment is not included in this classification. Routine monitoring programmes may vary depending on economical feasibility studies, but should not exceed a three year interval for this type of equipment.					

Table 2: Recommended frequency of insulating oil analyses on electrical equipment.

Analysis	Test set
Dissolved gas analysis (DGA)	1
Dielectric strength	1/2/3/4
Moisture content	1/2/3/4
Acidity	1/2/3/4
Furanic analysis	2
Colour	2/3/4
Dielectric dissipation factor (Tan delta)	2/3/4
Sediment and sludge	2/3/4
Interfacial tension	2/3/4
Particle quantification	3/4
Polychlorinated Biphenyl (PCB)	3/4
Carbon composition	3
Aromatics	3
Viscosity	3
Corrosive sulphur	3/4
Aniline point	3
Silicon/silicone	3/4
Resistivity	3
Inhibitor content/FTIR verification	2/3/4
Oxidation stability	3
Flash point	3
Density	3
Gassing tendency	3
Passivator content	2/3
Pour point	3
Polyaromatic hydrocarbons	3
Appearance	3/4

Table 3: Test sets required.

sample frequency will be set to instruct technical personnel. Once the work order is generated the sampler must prepare to take the sample and deliver it to the laboratory for analysis. Depending on what chemical analysis is required, the laboratory will produce a technical report outlining the results. From this data an interpretation will be made on the health of the transformer. These results can be kept in a database for later referral and retrieval.

There are a number of activities within the overall process, some more complex than others.

- Sampling frequency setting
- Scheduling the samples
- Sampling
- Analysis of chemicals and gases within the oil
- Interpretation and engineering
- Re-scheduling
- Data storage and management

Sample frequency setting

In this process, there are simple and effective methods and some complex methods of setting of sample frequencies. Firstly, the simple method is to classify the transformers using a well known standard as a guide. The IEC classes transformers into voltage classes. The higher the voltage of the transformer the higher criticality or more critical the unit is. However, this may not suit all cases, but a transformer can be placed into a class due to its criticality within the network or production process it supplies. (E.g. a furnace transformer may be of a low voltage class, but if the process it supplies is lost the down time and production losses are such a nature that it is justified that the unit is re-classified to a higher class. However, it is recommended that the risk classification method is used in these cases (see method 1 and 2 in the following text).

The Eskom standard (previously NRS079 – 1:2004) 32-406 classifies the transformers into the classes shown in Table 1.

Recommended sample frequencies (according to classes): are given in Table 2.

Table 3 lists the test sets required for different types of analysis.

Test set 4 is normally done for quality assurance after delivery of oil has been received.

Note that test set 3 is normally done when assessing oils for setting up purchasing contracts. Eskom has recently done extensive research into which oils to use. However some of these test are used to monitor the quality of the oil and for

Test set	Description	Minimum sample container required
Test set 1	Routine	• 1 litre sampling tin / • or 1 litre tin and 50 ml glass syringe
Test set 2	Age assessment	3 x 1 litre tins
Test set 3	Initial approval and annual verification tests	2 x 5 litre tins (new aluminium containers)
Test set 4	Quality assurance criteria tests (prior to transfer of oil into Eskom containers i.e. drums, bags, electrical apparatus, iso-tanks etc.)	• 2 x 1 litre sampling tins (new), • 2 x 200 ml plastic bottle completely full, • 1 X 200 ml 80% full, • 1 X ISO Certified clean glass bottle 80% full

Table 4: Sample container requirements.

Process criticality – Total loss of process capability	60
Process criticality – semi loss of process capability	25
Process criticality – small loss of process capability	15
Process criticality – no loss of process capability	0

Table 5: Shows weight according to criticality.

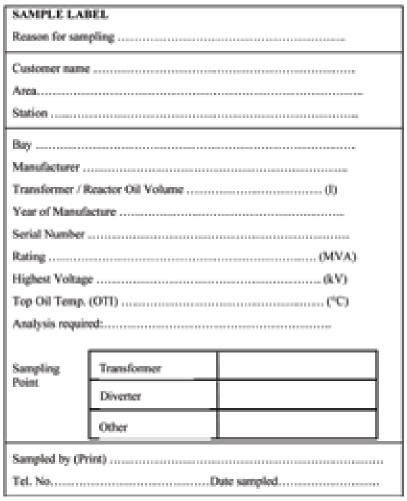
cross contamination after transportation or processing.

In contrast to the above, a risk analysis approach could also be used to determine the frequency at which a fleet of transformers are monitored. This method uses the criticality of the unit in the network and the current condition of the unit to determine the sample frequency. Two methods can be employed and both can give relatively good results.

Method 1

This method uses a single weighted score for particular group of criteria has shown in Table 5. The score is then divided with maximum possible score to obtain a per unit value (1 being the highest). These scores are added together for the different groups and a final score for that unit is given. With some technical input from engineers and field staff this can work well.

Example 1: if the chosen process criticality is Small Lost of Process (15) then the score



SAMPLE LABEL
Reason for sampling ....
Customer name ....
Area..........
Station ....
Bay ....
Manufacturer ....
Transformer / Reactor Oil Volume .... (l)
Year of Manufacture ....
Serial Number ....
Rating .... (MVA)
Highest Voltage .... (kV)
Top Oil Temp. (OTI) .... (°C)
Analysis required:..........

Sampling Point		
	Transformer	
	Diverter	
	Other	

Sampled by (Print) ....
Tel. No. ....Date sampled..........

Fig. 2 Sample label.

for this group will be 15/60 (60 being the maximum score possible within the group). Once all the groups are assessed then the scores are added together. Based on the score obtained a sample frequency can be determined considering some of the financial implications and other factors.

Method 2

Being similar to the above the single weighted score now is split between the group e.g. Process Criticality (30) and the question weight:

Example 2: if the chosen process capability is Small Lost of Process (15) then the score for this group will be 15/60 (60 being the maximum score possible within the group). This value is then multiplied by the group score (30 x 0,25) and then the group scores are added to obtain a risk factor. The higher the risks factor the shorter the period between samples.

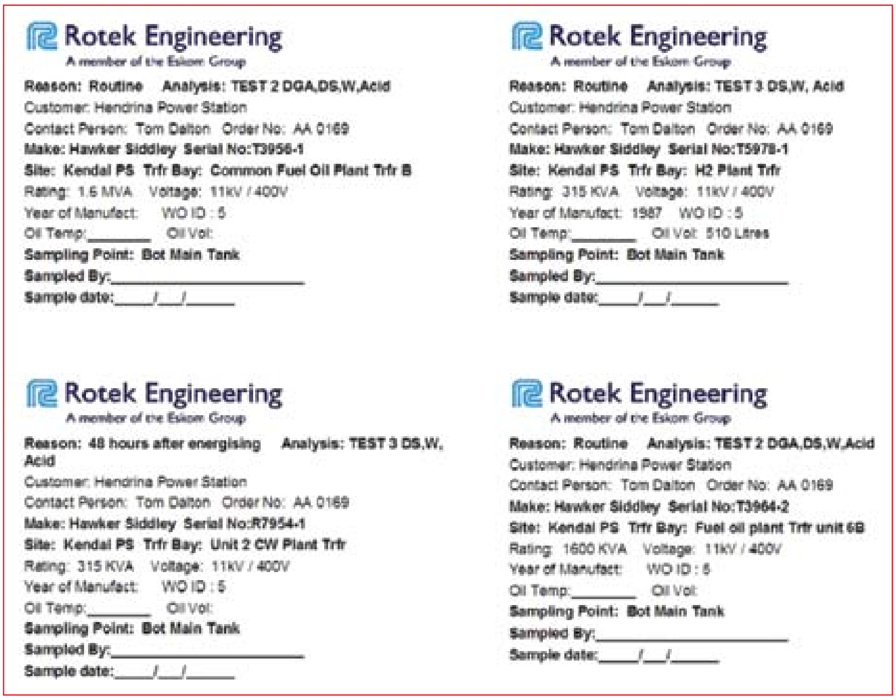
As can be seen from the above this can become complex, but these methods can be refined and is in line with reliability centred maintenance practices.

Scheduling the samples

Scheduling work can be done in all computerised maintenance packages. However, as a suggestion to ease the job of the sampler, it may pay to have the work folder and sample label printed at the same time. The sample label should have at least the information shown in Fig. 2. An example of a typical printed labels is shown in Fig. 3.

Sampling

Taking the sample from the transformer should be taken very seriously. This work is often left to untrained and unskilled staff (and some times to the illiterate). A common mistake and yet we base a multimillion Rand decision on the results that are obtained from the sample taken. It is strongly recommended that the sampler is a trained artisan who has been certified as competent to take a sample. Over last five years the technology and the way samples are taken has changed



Rotek Engineering
A member of the Eskom Group
Reason: Routine Analysis: TEST 2 DGA,DS,W,Acid
Customer: Hendrina Power Station
Contact Person: Tom Dalton Order No: AA 0169
Make: Hawker Siddley Serial No:T3956-1
Site: Kendal PS Trfr Bay: Common Fuel Oil Plant Trfr B
Rating: 1.6 MVA Voltage: 11kV / 400V
Year of Manufact: WO ID : 5
Oil Temp:_______ Oil Vol:
Sampling Point: Bot Main Tank
Sampled By:____________________
Sample date:____/__/_____

Rotek Engineering
A member of the Eskom Group
Reason: Routine Analysis: TEST 3 DS,W, Acid
Customer: Hendrina Power Station
Contact Person: Tom Dalton Order No: AA 0169
Make: Hawker Siddley Serial No:T5978-1
Site: Kendal PS Trfr Bay: H2 Plant Trfr
Rating: 315 KVA Voltage: 11kV / 400V
Year of Manufact: 1987 WO ID : 5
Oil Temp:_______ Oil Vol: 510 Litres
Sampling Point: Bot Main Tank
Sampled By:____________________
Sample date:____/__/_____

Rotek Engineering
A member of the Eskom Group
Reason: 48 hours after energising Analysis: TEST 3 DS,W, Acid
Customer: Hendrina Power Station
Contact Person: Tom Dalton Order No: AA 0169
Make: Hawker Siddley Serial No:R7954-1
Site: Kendal PS Trfr Bay: Unit 2 CW Plant Trfr
Rating: 315 KVA Voltage: 11kV / 400V
Year of Manufact: WO ID : 5
Oil Temp:_______ Oil Vol:
Sampling Point: Bot Main Tank
Sampled By:____________________
Sample date:____/__/_____

Rotek Engineering
A member of the Eskom Group
Reason: Routine Analysis: TEST 2 DGA,DS,W,Acid
Customer: Hendrina Power Station
Contact Person: Tom Dalton Order No: AA 0169
Make: Hawker Siddley Serial No:T3964-2
Site: Kendal PS Trfr Bay: Fuel oil plant Trfr unit 6B
Rating: 1600 KVA Voltage: 11kV / 400V
Year of Manufact: WO ID : 5
Oil Temp:_______ Oil Vol:
Sampling Point: Bot Main Tank
Sampled By:____________________
Sample date:____/__/_____

Fig. 3: Printed labels.

dramatically. At the Eskom laboratory it can be seen that the quality of the sample can often be attributed to the attitude and training of person who took the sample.

Cleanliness is one of the keys to a successful sample. Sample points are often caked with dirt (a combination of dust and oil). This must be cleaned and prepared correctly so as not contaminate the sample with dirt or other foreign matter. Further, flushing the sample point and rinsing the container adequately is paramount and ensuring the sample is representative of the body of oil being sampled. A sampling kit (with the necessary flanges, piping and tools etc.) goes a long way in taking a good sample.

Further, the sampler needs to known and understand where samples should be taken and be mindful of the complexities of some of the sample points.

The sampler must check that he is taking the sample from the correct sample point and the correct transformer. He needs to check the container into which he is sampling and for what analysis the sample will be used, as this will dictate the type of vessel that should be used. Some modern transformers are fitted with online gas-in-oil monitors and these units cannot be removed.

Currently there are a number different sample vessels that can be used, some better than others. Some analysis requires that a specific sampling container is used. In general the following containers are acceptable:

- Round or square 1 litre tin with welded seems and soldered joints (please ensure that the seal in the lid is of the Nitrile type). This is the most often used container for general sampling (dissolved gases, water, dielectric strength and acidity analysis).
- Glass syringe 50 ml (both the jacket and the plunger ground to fit one another). Used mainly for dissolved gas analysis.
- Glass bottles (dark amber or clear) for general sampling, but not preferred due breakages and eliminating the air bubble.
- Small clear or amber bottle (40/50 ml) for Polychlorinated Biphenyl sampling.
- Plastic bottles (100 ml) for corrosive sulphur analysis and silicone contamination analysis (80% filled).
- ISO certified clean jar (200 ml) for particle count analysis (oil cleanliness samples) only 80% filled.

The sampler also needs to be mindful of the environment and must dispose of the scrap oil in the correct manner. Either, return the scrap oil to a regenerating facility or to responsible scrap oil dealer.

Lastly the sampler must deliver (or have) the samples delivered to the laboratory without causing the sample to deteriorate. It is best to keep the samples at a constant temperature and room temperature is preferred. Depending on the sample container the less the oil comes in contact adverse conditions the better.

Good documentation handling goes a long way. Ensure that the laboratory is supplied the following:

- Type of analysis (per sample)
- Number of samples
- The priority of the samples
- Billing information
- Samples correctly labelled

Contact Tom Dalton, Rotek Engineering, Tel 011 629-4702, tom.dalton@eskom.co.za ❖