Eskom	Standard	Technology

Title: **Sampling and Testing of Mineral Insulating Oil for Power Transformers Within Generation Division Standard**

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1. INTRODUCTION

“This document consists of ‘Sampling and Testing of Mineral Insulating Oil for Power Transformers Within Generation Division Standard’”

2. SUPPORTING CLAUSES

2.1 SCOPE

The document lay down a standard for the:

i. management,

ii. sampling,

iii. quality assurance and

iv. testing and oil acceptance

of mineral insulating oil for power transformers to limit and reduce disastrous conditions from occurring in power transformers.

2.1.2 Purpose

The document lay down a standard for the:
(i) management,
(ii) sampling,
(iii) quality assurance and
(iv) testing and oil acceptance

of mineral insulating oil for power transformers to limit and reduce disastrous conditions from occurring in power transformers.

2.1.3 Applicability

This standard is applicable to all oil immersed power transformers (i.e. Generator, Unit and Service transformers and others) within the Generation Group.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

The following documents contain provisions that, through reference in the text, constitute requirements of this standard. At the time of publication, the editions indicated were valid. All standards and specifications are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the documents listed below. Information on currently valid national and international standards and specifications can be obtained from the Technology Standardisation Department at Megawatt Park.

[1] SANS 555:1985, Mineral insulating oil for transformers and switchgear (uninhibited).

[2] IEC 60422:1989, Supervision and maintenance guide for mineral insulating oils in electrical equipment.

[3] IEC 60156:1995, Insulating liquids — Determination of the breakdown voltage at power frequency — Test method.

[4] ESKSCAAR9 Rev.0: Specification for new transformer oil.

[5] ESKPVABK3 Rev.0: Transportation of transformer insulating oil

[6] ESKASAAC2: Management of polychlorinated biphenyls (PCB).

[7] ESKAGAAR5 Rev.0: Oil sampling points on power transformers

[8] ESKASABW5 Rev.0: Insulating oil drum labelling, identification and storage

[9] OPR 6204 Rev.5: Operating regulations for high-voltage systems.

[10] Appendix A

[11] Appendix B

[12] Appendix C

[13] Appendix D

[14] Appendix E

[15] Appendix G

2.2.2 Informative

[16] Appendix F

[17] Appendix H

[18] Appendix I

[19] Appendix J

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2.3 DEFINITIONS

Definition	Description
Energising	When voltage is applied to the power transformer but prior to placing it on load
Filtered oil (polishing)	Oil that has been filtered to improve the dielectric strength to greater than 70 kV/2,5 mm gap and a water content to less than 10 mg/kg (ppm).
Large power transformers	Generator transformers, Unit transformers and Service transformers.
Long Storage	Storage of a power transformer for a period longer than 3 months
New oil	Virgin oil, which complies in all respects with requirement of ESKASCAAR9 Rev.0
Regenerated oil	Processed or re-refined used oil, which complies in all respects with SANS 555. However, the following tests limits shall be met on point of loading and prior to energising: a. Dielectric strength (DS) greater than 70 kV/2,5 mm gap. b. Water content (WC) less than 10 mg/kg (ppm).
Small power transformers	All the remaining oil immersed transformers available at power stations

Specialist	An experienced Eskom person who regularly performs specific tasks for which he has been specially educated and trained and of which he has and maintains an in-depth knowledge
Topping-up	Refers to the action of correcting the oil level in a conservator tank, where the level of the oil is not lower than the Buchholz relay. If the oil is below the Buchholz level, the filling procedure of a respective power station shall apply.

2.3.2 Classification

a. **Controlled Disclosure:** Controlled Disclosure to External Parties (either enforced by law, or discretionary)

2.4 ABBREVIATIONS

None

2.5 ROLES AND RESPONSIBILITIES

None

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

None

3. SAMPLING AND TESTING OF MINERAL INSULATING OIL FOR POWER TRANSFORMERS WITHIN GENERATION DIVISION STANDARD

3.1 REQUIREMENTS

3.1.1 Safety precautions

Safety precautions shall be observed at all times when taking oil samples. The power station HV operating procedure, OPR 6204 Rev 5, shall be adopted when entering the power transformer yard.

3.1.2 Station and laboratory responsibilities and actions

The details of power station-specific responsibilities and actions will depend on the management instructions in place at each power station, however below are the overall station and laboratory responsibilities. Power stations are required to have a detailed document entailing responsibilities of different persons.

3.1.2.1 Power Station

The power station shall be responsible for:

a. Taking oil samples from the plant at the frequencies required by this standard, or as deemed necessary by the system engineer. The system engineer is advised to consult with either the Corporate Consultant (Generation Technology Department) or Senior Consultant (Petroleum Chemistry), Eskom Enterprise Laboratory Services and other transformer system engineers or transformer specialists prior to altering the frequencies. However, the system engineer is still required to receive authorisation from the relevant power station management prior to altering the frequencies. The oil sample shall be carried out in accordance with the procedures stated in **Appendix's A** and **D**.

b. delivering oil samples for analysis to a laboratory approved by the Senior Consultant (Petroleum Chemistry), Eskom Enterprise Laboratory Services.

c. the handling and storage of all oils received for use at the station and oil sent for regeneration or disposal.

d. ensuring that equipment where PCBs are identified is clearly marked and managed in accordance with ESKASAAC2.

e. ensuring that only approved new , regenerated or filtered oil is used.

f. nominating the site representative(s) to whom oil test results shall be directed.

g. monitoring trending oil sample results and recommendations, including taking the recommended action timeously.

h. maintaining all relevant records.

3.1.2.2 Laboratory

The Senior Consultant (Petroleum Chemistry) at Eskom Enterprise Laboratory Services shall be responsible for:

a. the timely analysis of oil samples received and recommendations of action in consultation with other specialists.

b. informing the appropriate power station of the results of the oil test analysis, and giving recommendations. The maximum response time after the analysis of the oil samples shall be as tabled below:

Table 1: Acceptable response times

Description	Response time
Energising oil samples	2 hours
Generator transformer routine oil samples	1 week
Unit transformer routine oil samples	2 weeks
Service transformer and others routine oil samples	2 weeks
Long term plant health indicator samples	2 weeks

c. maintaining, updating and safeguarding an oil test results databank system, which must be made available to power stations.

d. approving, auditing and certifying laboratories and their staff who are experienced in handling insulating oils. Re-approval shall be required when staff is changed.

e. keeping abreast of the latest developments in oil technology through research and updated methodology.

3.1.2.3 On-Line Dissolved Gas Analysers

Where True Gas on-line dissolved gas analysers are fitted to a transformer, the oil sampling point for laboratory analysis shall be located before the on-line analyser (i.e. on the incoming line to the on-line analyser).

All results from on-line dissolved gas analysers shall be checked against laboratory tests of an oil sample, at least once per annum.

3.1.3 Operational

3.1.3.1 Sampling requirements

The following tasks shall be performed in accordance with the procedures referenced;

3.1.3.1.1 General

a. Tin oil sampling shall be carried out as described in Appendix A.

b. Tin oil samples shall be clearly and fully labelled as illustrated in Appendix B.

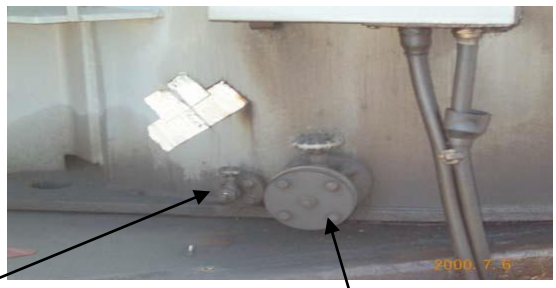
c. Syringe oil sampling shall be carried out as described in Appendix D and shall be clearly labelled.

d. Oil (tin and syringe) samples shall be protected against rough handling and extreme temperatures during storage and transport. This shall be carried out as per the requirement of ESKPVABK3 Rev.0 Transportation of transformer insulating oil. The syringe samples shall be placed and transported in the syringe kit provided.

e. An approved sampling device for taking samples from drums to test for dielectric strength (DS) and water content (WC) is detailed in **Appendix C**.

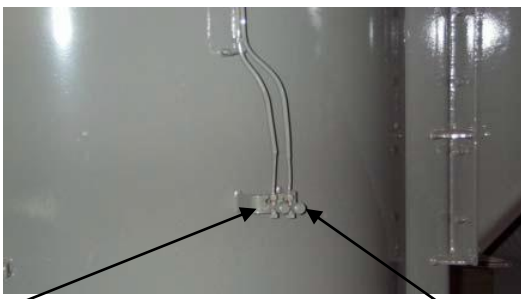
3.1.3.1.2 Oil sampling points

The power transformer bottom main tank oil sampling point shall be used as the routine sampling point and it shall be marked accordingly. Whilst the power transformers bottom oil drain valve shall be used as the routine sampling point on power transformers without the bottom main tank oil sampling point and shall be marked accordingly as well.



Refer to A.3.2 in **Appendix A** for applicable oil sampling procedure.

To ensure consistency for trending purposes, stations that were originally using the Buccholtz relays as the routine sampling points shall continue to do so and the sampling point shall be marked accordingly. However, the particular station shall ensure where necessary that the inadequate sized copper tubing and/or valve is replaced to obtain a satisfactory flow of approximately 500 ml/min. Or to allow the sampler to take a maximum of 5 minutes to fill a 1 litre sample container.



Refer to A.3.1 in **Appendix A** for applicable oil sampling procedure.

3.1.3.1.3 Syringe oil sampling points

The transformer main tank drain valve or bottom main tank sampling point shall be used for taking syringe oil samples. Refer to Annex D for information on syringe oil sampling procedure. The syringe sample shall be taken to perform the following tests:

- Oxygen level
- Water content in the paper insulation and
- Dissolved Gas Analysis (DGA) when required. The DGA shall be analysed using “head space” technology.

3.1.3.1.4 Oil sampling frequency

Table 2 outlines the frequencies at which the tests outlined shall be performed on the tin and syringe oil samples taken from the bottom main tank of the power transformers while oil samples from the selector and diverter switches shall be taken from the recommended sampling points. A syringe oil sample shall be used to perform DGA, WC and O2 tests while the other remaining tests shall be performed using oil from the tin oil samples.

	Energisation				**Routine**			**Outage**
	Before	**48 hours after**	**1 week after**	**1 monthly & 3 monthly after**	**6 monthly**	**Annually**	**2 Yearly**	**Before De-commissioning**
Generator Transformers Tests	O2 DGA WC RS DS A Sludge Tan S IFT Colour Furanic	DS WC DGA	DS WC DGA	DS WC DGA A	DS WC DGA A Sludge (f) O2 RS	(a) Colour (b) IFT (c) Tan S (d) Furanic	(a) AA (b) CS (c) Ar (e) PF VO	O2 DGA WC RS DS A Sludge Tan S IFT Colour Furanic
Unit Transformers Tests	DS WC DGA O2 A (f) Furanic	(a) DS (b) WC (c) DGA	(a) DS (b) WC (c) DGA	(a) DS (b) WC (c) DGA (d) A		(a) DS (b) WC (c) DGA (d) A (e) Sludge (f) O2 (g) RS	(a) AA (b) CS (c) Ar (d) PF VO (e) Colour (f) IFT (g) Tan S (h) Furanic	(a) O2 (b) DGA (c) WC (d) RS (e) DS (f) A (g) Sludge (h) Tan S (i) IFT (j) Colour (k) Furanic
Service Transformers Tests	(a) DS (b) WC (c) DGA (d) O2 (e) A	(a) DS (b) WC (c) DGA	(a) DS (b) WC (c) DGA	(a) DS (b) WC (c) DGA (d) A		(a) DS (b) WC (c) DGA (d) A (e) Sludge	(a) AA (b) CS (c) Ar (d) PF VO (e) Colour	(a) O2 (b) DGA (c) WC (d) RS (e) DS

	(f) Furanic					(f) O2 (g) RS	(f) IFT (g) Tan S (h) Furanic	(f) A (g) Sludge (h) Tan S (i) IFT (j) Colour
Small power transformer	(a) DS (b) WC (c) DGA (d) A (e) O2	(a) DS (b) WC (c) DGA	(a) DS (b) WC (c) DGA				(a) DS (b) WC (c) DGA (d) A (e) O2	(a) O2 (b) WC (c) DS (d) A (e) Furanic
Tap Changers – Diverter Switch	(a) DS (b) WC					(a) DS (b) WC		

Table 2: Sampling frequencies and test types

Abbreviations: O2: Oxygen, DGA: Dissolved Gas analysis, RS: Relative saturation, DS: Dielectric strength, A: Acidity, Tan S: Tan delta, IFT: Interfacial Tension, WC: Water Contents, Furanic: 2-Furfural, AA: Accelerated Ageing, CS: Corrosive Sulphur, PF VO: Doble Tests, Ar: Aromatics

The emergency samples – is a sample that shall be taken on the power transformer

i. After a Buchholz alarm

ii. After a through fault in the HV yard

When the site suspects an internal fault inside the power transformer tank to determine and confirm the severity of the fault inside the power transformer tank.

NB:

1. On outage, if A, Sludge, Tan S, ITF, Colour and Furanics were performed in less than 3 months prior to the outage, these tests shall be performed after 6 months for generator transformer and after 1 year for the unit and service transformers and after 2 years on small power transformers.
2. Sampling of the selector switch shall be as per requirements from the site transformer system engineer in consultation with the relevant Generation Consultants and other relevant knowledgeable Eskom transformer personnel to confirm the originality of the fault that is present in the power transformer tank. This assumes that the valve between the transformer main tank and selector switch is opened during the normal operation of the power transformer. The system engineer is still required to inform and seek authorisation from the relevant site management prior to sampling the selector switch.

3.1.3.2 Oil requirements

3.1.3.2.1 Storage of transformer oil

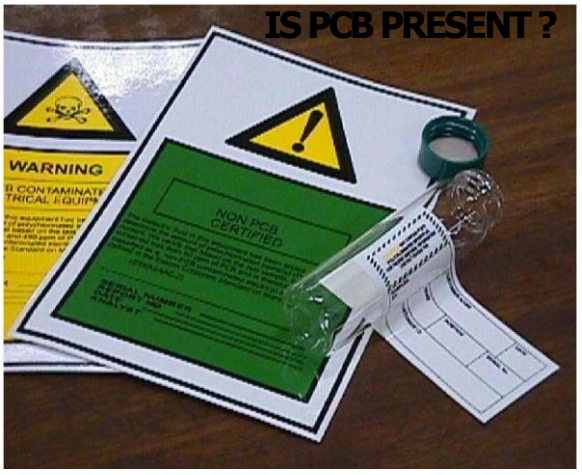
Small drums (20 l) shall always be stored indoors, oil tested and used immediately after unsealing. Large drums 210 l) shall be stored as described in **Appendix E**, ensuring that there is a head of oil above the bungs to prevent the entry of water, see picture. The seals shall be removed under cover, and the oil tested immediately and, if possible, used on the completion of the tests. The prolonged storage of broached drums shall be avoided. The drum storage and labelling shall conform to the requirements of ESKASABW5 Rev 0: *Insulating oil drum labelling, identification and storage.*

√: Acceptable ×: Not Acceptable

The use of VAC-PACK liners shall only be acceptable from approved suppliers using approved filling procedures.

Tanks for bulk storage shall be completely sealed with properly fitted and maintained dehydrating breathers. If possible, all valves and communicating pipelines shall be protected from the weather and particularly from driving rain.

3.1.3.2.2 Polychlorinated Biphenyl (PCB) contamination



Testing for PCB contamination shall be done by Eskom Enterprise Laboratory Services.

All oil in bulk storage tanks, particularly at workshops, which is intended for re-use in equipment, independent of voltage rating, shall be tested for PCB contamination to avoid the spreading thereof. Appropriate labeling shall apply for different PCB contamination levels, see picture. Refer also to ESKASAAC2: *Management of polychlorinated biphenyls (PCB).*

All oil submitted for reprocessing or regeneration shall also be tested for PCB contamination, unless relevant certification, which has been verified by the Senior Technologist - Petroleum Chemistry, is available.

All virgin oil purchased shall have a “zero count PCB” certificate, and records thereof shall be kept. Refer to ESKSCAAR9 Rev.0: *Specification for new transformer oil.*

PCB contaminated oil shall be stored separately in containers which are clearly marked and dealt with in accordance with ESKASAAC2.

Retrofilled transformers shall be re-tested for PCB content and re-certified one year after retrofilling.

3.1.3.2.3 Oil containers

Stationary tanks, oil bags or drums dedicated to insulating oil only, shall be used for oil storage. Oil drums shall be stored in accordance with the procedure in Appendix E.
Oil containers contaminated with dirty oil shall not be used for new, regenerated and filtered oil, unless such containers are first properly cleaned.

3.1.3.2.4 Oil suppliers

The oil supplier shall guarantee that the oil delivered complies with the “zero count PCB” requirement. This guarantee shall be in the form of a certificate and records thereof shall be kept for auditing purposes.

The oil supplier shall guarantee that, at the point of loading into dedicated supplier/Eskom tankers, the oil conforms to the requirements of “new oil” or “regenerated oil”. This guarantee shall be in the form of a certificate, of which a copy shall accompany the delivery note. Records thereof shall be kept for auditing purposes.

a. Oil supplied in tankers

On delivery at site, and before transfer to another container (i.e. drums, bags, power transformer, etc.), the oil shall be tested for DS. The minimum DS shall be 60 kV/2,5 mm gap. This sample shall be taken at the physical point of delivery, i.e. the end of the tanker supply hose.

b. Oil supplied in drums

Drums are sealed at the point of loading by the supplier and site testing on delivery is therefore not necessary. However, oil in drums shall be tested before use. The minimum DS shall be 60 kV/2,5 mm gap.
Transportation and storage: Drums shall be positioned either with the two bungs in a horizontal line position or upside down i.e. bungs down. Refer to Appendix E.

c. Regeneration of oil

Only batch regeneration is acceptable. The oil shall be re-refined batch-wise to comply in all respects with SANS 555 and be tested to the requirements of SANS 555 Table 1, with the exception that prior to use, the oil shall comply with the DS ≥ 70 kV/2.5 mm gap and WC ≤ 10 ppm. Certification of compliance shall be kept on each batch of oil regenerated for audit purposes.

d. Dielectric strength, water content and acidity

The DS test shall be performed in accordance with IEC 60156.
All oil supplied to site shall be pre-processed to be degassed and shall have a minimum DS of 70 kV/2,5 mm gap and a maximum WC of 10 mg/kg, with an acidity (A) of not more than 0,03 mg KOH/g.

3.1.3.2.5 Oil for filling units

Only “new oil” shall be used for the first filling of new power transformers or power transformers where all the insulation has been replaced with new insulation (see Annex F).
Oil filling shall only be done by or under the supervision of specialists. The manufacturer’s filling procedure and specifications shall be followed.

3.1.3.2.6 Oil for topping up units

Caution — Topping-up refers to the action of correcting the oil level in a conservator tank. If the oil is below the Buchholz level, the filling procedure shall apply (refer to 3.1.3.2.5).

Only new or regenerated oil supplied in tankers or drums, as referred to in 3.1.3.2.4 b) or 3.1.3.2.4 c) where applicable, shall be used for topping up.

3.1.3.2.7 Transformer oil tests and acceptance criteria: new or repaired units

Caution — where the test limits for oil as specified by the manufacturer are more stringent than those specified below, the manufacturer's test limits shall apply. This shall be applicable to units of all voltage ratings.

The oil tests outlined in Table 2 and Table 3 shall be carried out by ERID oil laboratory in accordance with acceptable national and international standards and procedures.

Section A – Oil tests and acceptance criteria before filling/topping and commissioning

		Before filling / topping up	**Before commissioning**	**Units in service**
Generator transformer	#	Test and acceptance criteria	Test and acceptance criteria	Test and acceptance criteria
	1	FTIR (oil type verification) – Depends on oil ordered		
	2	Water content - **<**10 ppm	Water content - **<**10 ppm	Water content - **<2**0 ppm
	3	Dielectric strength - **>**70 kV	Dielectric strength - **>**70 kV	Dielectric strength - **>**60 kV
	4	Dielectric dissipation factor (Tan delta) - **<** 0,005		
	5	Interfacial tension - **>** 40 mN/m		
	6	Test for PCB – Non detectable		
	7	Acidity - **<** 0.01		Acidity - **<** 0.05
	8	Test for silicon (ICP) - **<** 2 ppm		
	9	Corrosive sulphur – Non detectable		
	10	Sludge – Non detectable		
	11	Appearance – Clear from sediments and suspended		
Unit and service transformers	1	FTIR (oil type verification) – Depends on oil ordered		
	2	Water content - **<**10 ppm	Water content - **<**10 ppm	Water content - **<2**0 ppm
	3	Dielectric strength - **>**70 kV	Dielectric strength - **>**70 kV	Dielectric strength - **>**60 kV
	4	Dielectric dissipation factor (Tan delta) - **<** 0,005		
	5	Interfacial tension - **>** 40 mN/m		
	6	Test for PCB – Non detectable		
	7	Acidity - **<** 0.01		Acidity - **<** 0.05
	8	Test for silicon (ICP) - **<** 2 ppm		
	9	Corrosive sulphur – Non detectable		
	10	Sludge – Non detectable		
	11	Appearance – Clear from sediments and suspended		
Small power transformers	1	FTIR (oil type verification) – Depends on oil ordered		
	2	Water content - **<**10 ppm	Water content - **<**10 ppm	Water content - **<**20 ppm
	3	Dielectric strength - **>**70 kV	Dielectric strength - **>**70 kV	Dielectric strength - **>**60 kV
	4	Dielectric dissipation factor (Tan delta) - **<** 0,005		
	5	Interfacial tension - **>** 40 mN/m		
	6	Test for PCB – Non detectable		
	7	Acidity - **<** 0.01		Acidity - **<** 0.05
	8	Test for silicon (ICP) - **<** 2 ppm		

	9	Corrosive sulphur – Non detectable		
	10	Sludge – Non detectable		
	11	Appearance – Clear from sediments and suspended		
Diverter Switch	1	FTIR (oil type verification) – Depends on oil ordered		
	2	Water content - **<**10 ppm	Water content - **<**10 ppm	Water content - **<**10 ppm
	3	Dielectric strength - **>**70 kV	Dielectric strength - **>**70 kV	Dielectric strength - **>**60 kV
	4	Dielectric dissipation factor (Tan delta) - **<** 0,005		
	5	Interfacial tension - **>** 40 mN/m		
	6	Test for PCB – Non detectable		
	7	Acidity - **<** 0.01		Acidity - **<** 0.05
	8	Test for silicon (ICP) - **<** 2 ppm		
	9	Corrosive sulphur – Non detectable		
	10	Sludge – Non detectable		
	11	Appearance – Clear from sediments and suspended		
Selector Switch	1	FTIR (oil type verification) – Depends on oil ordered		
	2	Water content - **<**10 ppm	Water content - **<**10 ppm	Water content - **<**10 ppm
	3	Dielectric strength - **>**70 kV	Dielectric strength - **>**70 kV	Dielectric strength - **>**60 kV
	4	Dielectric dissipation factor (Tan delta) - **<** 0,005		
	5	Interfacial tension - **>** 40 mN/m		
	6	Test for PCB – Non detectable		
	7	Acidity - **<** 0.01		Acidity - **<** 0.05
	8	Test for silicon (ICP) - **<** 2 ppm		
	9	Corrosive sulphur – Non detectable		
	10	Sludge – Non detectable		
	11	Appearance – Clear from sediments and suspended		

Section B - CORRECTIVE MEASURES

Item	Corrective measure to be taken
1	None – reject oil
2	Purify using a MOP (Mobile oil plant)
3	Purify using a MOP
4	Oil regeneration plant (Clay filter)
5	Oil regeneration plant (Clay filter)
6	None – reject oil
7	Oil regeneration plant (Clay filter)
8	None – reject oil *Causes excessive foaming*
9	None – reject oil
10	Oil regeneration plant (Clay filter)
11	Oil regeneration plant (Clay filter)

Section C - TEST REQUIRED FOR RECORDS

#	Test	Acceptance criteria	Corrective measures to be taken
a	All of the test in Section A		
b	Full DGA analysis	None atmospheric gases	Degas
c	Furanics	For information	For record purposes
d	Oxygen stability	**5** 1.2 (Acidity) **5** 0.8 (Sludge percentage by mass)	For record purposes
e	Anti-oxidant additives	Depend on oil	For record purposes
f	Gassing tendency	**5** + 5 (+8) inhibited	For record purposes
g	Polycyclic aromatics	**<** 3	For record purposes
h.	Kinematic viscosity	Depend on oil class	For record purposes
i	Flash point	Depend on oil class	For record purposes
j	Pour point	Depend on oil *class (usually not a problem in South Africa)*	For record purposes
k	Colour	**<** 2	For record purposes
l	Density	0.895 Max	For record purposes
m	Resistivity @ 20 deg c	Typical values 1500 G.Qm	For record purposes
n	Resistivity @90 deg c	Typical values 450 G.Qm	For record purposes

Table 3: Transformer oil tests and acceptance criteria

Take note of the following:

1. On-site tests for topping-up oil
   Caution — the maximum test voltage of old versions of oil test equipment is 60 kV. This equipment may be used providing the 60 kV test level is held for at least 1 min.

2. Test limits for oil in units before re-energising

   a. Units on outage for less than 1 month may be re-energized without oil sample taken

   b. Units on outage for longer than 1 month, an oil sample shall be required. The unit shall only be re-energized if the sample analysis results are satisfactory.

3. Test limits for oil in units before commissioning

   a. All new or repaired units shall only be topped, filled and commissioned after the test results of the oil comply with the limits outlined in Table 3: Transformer oil tests and acceptance criteria

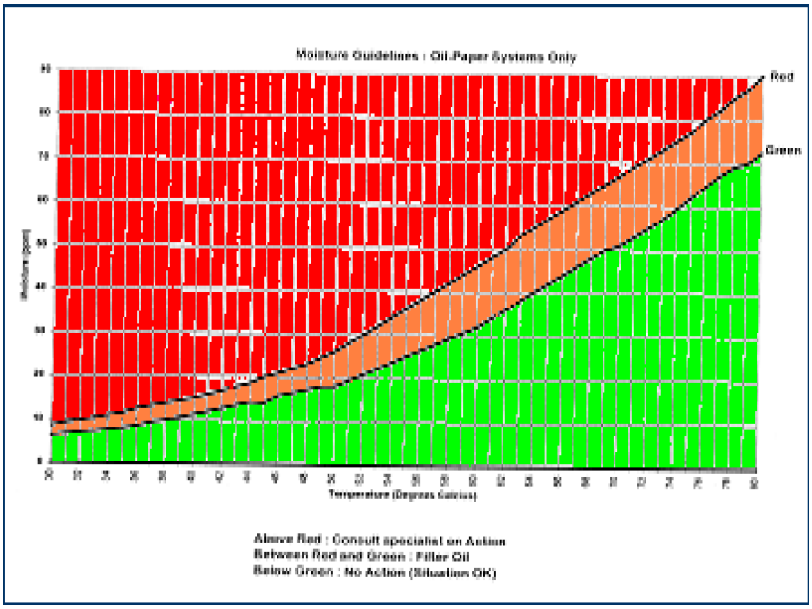
   b. The oil to be used shall comply with the requirements of 3.1.3.2.4 before filling the unit.

3.1.3.2.8 Test limits

The following test only act as gatekeepers as trending is key in analysing results of these test indicators.

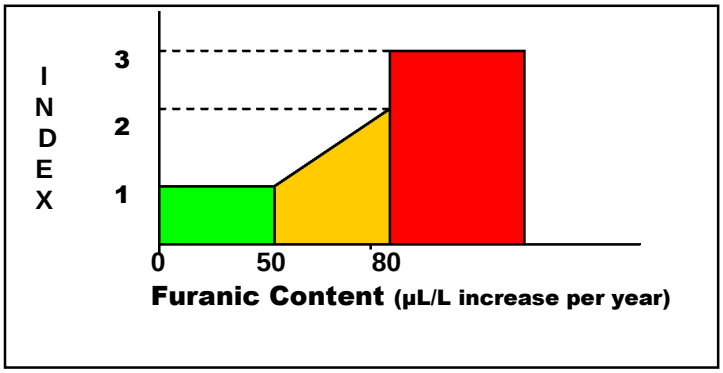
a. Water Content

The water content limits shall be as per the graph below. The acceptable water content is indicated by values in the green portion at different temperatures. While orange colour raises concerns and red colour signals immediate action to be taken by power station personnel.



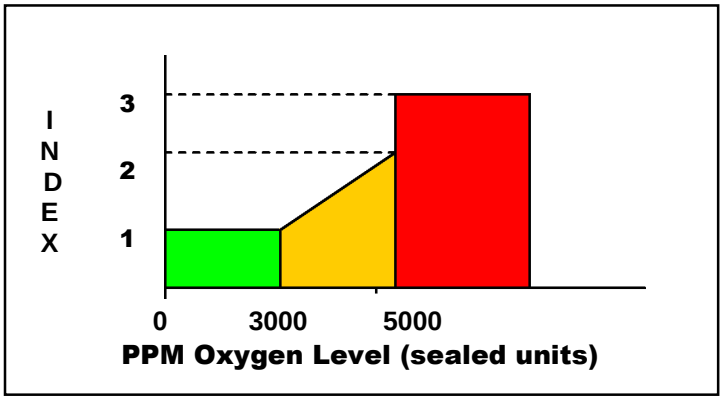
b. Furanics

The 2-Furfural compounds limits are to provide a guidance to predict the condition of the paper insulation in the power transformer. The acceptable limit is 50 parts per billion (ppb) per annum. The 2-Furfural compound amount exceeding 80 ppb per annum is a signal indicating the high rate at which the paper insulation is deteriorating. The power station personnel should guard against the paper condition deteriorating at this rate by limiting high power transformer operating temperatures. The tin sample oil must be used to perform the 2-Furfural test. Refer to Appendix A for tin sampling procedure.



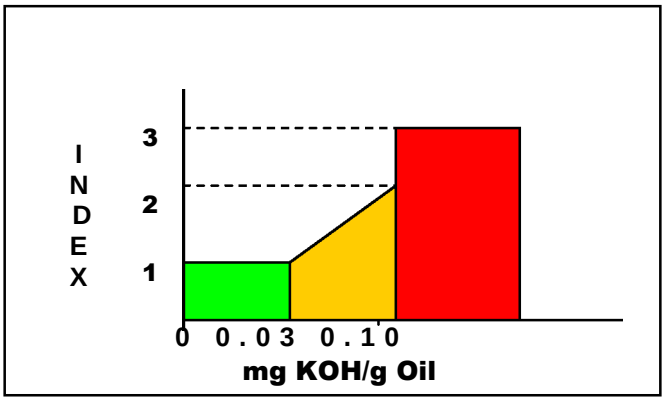
c. Oxygen

The permissible oxygen level in a power transformer that is fitted with an air cell in the conservator tank is 3000 ppm or less. This only acts as a guide as power transformer exposed to excessive temperatures/loading can result in elevated oxygen level being obtained. The oxygen level of 5000 ppm and above indicates the deterioration of the situation either due to air leaks or elevated temperatures. The oxygen level test must be performed using the oil that was received from the syringe sampling. Refer to Annex C for syringe sampling procedure.



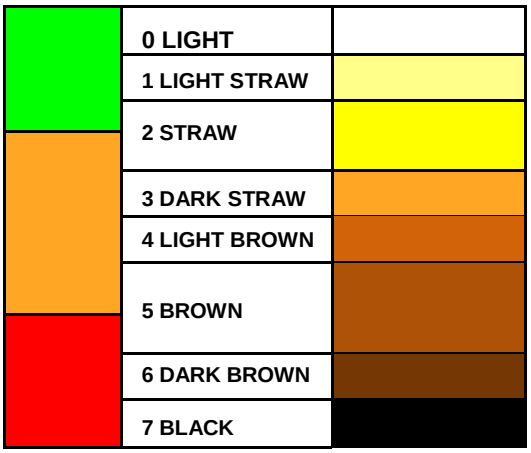
d. Acidity

The level of acid compounds in a power transformer is an indication of elevated temperatures and is harmful to the paper insulation, refer to picture.
The acidity of oil in a unit shall be related to the age of the unit. Decisions regarding the replacement or treatment of the oil in such units, based on the acidity concentration shall be made by the TSI oil laboratory together with transformer specialists who shall consider all relative factors.



e. Colour

The colour of the oil is an indication of the condition deterioration level of the insulating oil. The light oil colour is an indication of new and good oil while black oil colour is an indication of deteriorated oil particles. The acceptable level is 0 up to 4.



The oil colour with level between 3 and 5 signals the personnel of the deteriorating condition of the insulating oil. While oil level above 5 renders attention from the station personnel.

3.1.3.3 Test reports

ERID (Technology Strategy and Planning) shall maintain and safeguard an electronic databank accessible through Eskom's computer network. This information is considered to be a long-term asset to Eskom. It shall not preclude users from downloading results from the central database to serve their own particular data recording requirements.

Copies of all oil test results and reports produced by approved chemical laboratories other than Eskom Enterprise Laboratory Services, shall be incorporated in the central Technology Services International databank and the recommendations shall be verified.

4. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
	Document Approved by TDAC ROD 16 July 2013
L.P. Malaza	Electrical Plant Engineering Manager
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5. REVISIONS

Date	Rev.	Compiler	Remarks
November 2012	0.1	E.J. Mbokodo	Draft Document for review created from GGS 1026
December 2013	1	G.M. Mungwe	Final Document Authorised for Publication

6. DEVELOPMENT TEAM

The following people were involved in the development of this document:

- E.J. Mbokodo
- G.M. Mungwe
- L.P. Malaza

7. ACKNOWLEDGEMENTS

- None

APPENDIX A – TIN OIL SAMPLING PROCEDURE

(Normative)

Requirement: The tin oil sample shall be taken by a trained and accredited person

A.1 Precautions

Hazard: Do not climb onto "live" units to take oil samples.

a. Take data for the sample labels only from the unit's nameplate, and NOT FROM LOGBOOKS.
b. Use only the approved oil sample tins and labels.
c. Use only the marked sample points.

A.2 Tools and equipment

A.2.1 Buchholz sampling kit

a. One 6 mm × 200 mm tube
b. Sample tins
c. Sample labels
d. One 10 l bucket
e. Chamois leather

A.2.2 Main tank drain valve sampling kit

a. 50 mm valve flange and gasket
b. Hose coupling
c. One 1 m hose
d. Sample tins
e. Sample labels
f. One 10 l bucket
g. Chamois leather
h. Set of tools

Caution — An oil drum for waste oil shall be available on site. This oil shall be returned for recycling.

i. For correct water concentration, take routine samples only in fine weather.
ii. DO NOT touch or breathe onto oil sample.
iii. Clean the sampling flange and valves only with chamois leather to avoid fibres.
iv. Clean all sampling apparatus

Caution — If the sample oil does come into contact with the sampler's hands or breath, the sample shall be retaken. Fibres in the oil will drastically reduce the dielectric strength.

A.3 Procedure

A.3.1 Using Buccholtz relay sampling point for routine sampling purposes

Caution — The sample shall only be taken at ground level from the valve at the end of the tubing for degassing/sampling.

Appendix A
(Continues)

a. Complete a sampling label, giving all the requested information including the reason for sampling and the top oil gauge temperature (OTI - Oil Temperature Indicator). Transformer data shall be taken from the transformer nameplate.

b. Clean the sampling valve with chamois leather.

c. Open the valve and allow approximately 0,5 l of oil to run into the waste bucket.

d. Close the valve and connect the 6 mm × 200 mm tube to the valve.

e. Open the valve and again allow approximately 0,5 l of oil to run through the tube into the waste bucket.

f. Rinse the tin by half filling it with oil. Replace the cap and rotate the tin slowly, ensuring that the oil covers all areas inside the tin. Empty the tin into the waste bucket. Repeat twice.

Caution — When rinsing, do not shake the tin as foaming may occur. This will have an adverse effect on the test results, particularly the DGA, and possibly the DS, if tested soon afterwards.

i. Hold the tube in the neck of the tin and while avoiding foaming, fill the tin until the oil overflows. The tube shall not touch the oil at any stage.

ii. Place the tin on a flat surface and squeeze the sides very slightly until oil overflows. Replace the cap firmly before releasing the pressure.

iii. With the tin upside down, rotate the tin slowly while holding it close to the ear to listen for bubbles resulting from incomplete filling. Retake the sample if bubbles are heard.

iv. Ensure that samples arrive at the laboratory within one week.

A.3.2 Using transformer drain valve or bottom main tank sampling point for routine sampling

Caution — Samples shall only be taken from the transformer main tank drain valve or bottom main tank sampling point.

a. Complete a sampling label, giving all the requested information including the reason for sampling and the top oil gauge temperature (OTI — Oil Temperature Indicator). Transformer data shall be taken from the transformer nameplate.

b. Clean the sampling flange and valves with chamois leather.

c. Remove the plug, fit the hose coupling to the sampling flange and connect the sampling hose.

d. Open the drain valve and allow approximately 5 l of oil to run vigorously into the bucket, thereby rinsing the hose and valve and removing any free water that may have collected in the valve and flange.

e. Adjust the valve to give a steady flow. Do not operate the valve again until the sampling is complete.

f. Rinse the tin by half filling it with oil. Replace the cap and rotate the tin slowly, ensuring that the oil covers all areas inside the tin. Empty the tin into the bucket. Repeat twice.

Caution — When rinsing, do not shake the tin as foaming may occur. This will have an adverse effect on the test results, particularly the DGA and possibly the DS if tested soon afterwards.

i. Hold the tube in the neck of the tin and while avoiding foaming, fill the tin until the oil overflow. The tube shall not touch the oil at any stage.

ii. Place the tin on a flat surface and squeeze the sides very slightly until oil overflows. Replace the cap firmly before releasing the pressure.

Appendix A
(Continues)

iii. With the tin upside down rotate the tin slowly while holding it close to the ear to listen for bubbles resulting from incomplete filling. Retake the sample if bubbles are heard.

iv. Ensure that samples arrive at the laboratory within one week.

A.3.3 On-load tap changer diverter switch sampling

Caution — Samples shall only be taken from the tap changer diverter drain pipe valve or diverter conservator.

a. Since a diverter conservator typically holds only between 70 l and 200 l, depending on the transformer size, checking the diverter conservator oil level is essential after sampling and topping-up may be required.

b. Complete a sampling label, giving all the requested information including the reason for sampling and the top oil gauge temperature (OTI — Oil Temperature Indicator). Transformer data shall be taken from the transformer nameplate.

c. Clean the sampling flange and valves with chamois leather.

d. Remove the plug, fit the hose coupling to the sampling flange and connect the sampling hose.

e. Open the drain valve and allow approximately 2 l of oil to run vigorously into the bucket, thereby rinsing the hose and valve and removing any free water that may have collected in the valve and flanges.

f. Adjust the valve to give a steady flow. Do not operate the valve again until the sampling is complete.

g. Rinse the tin by half filling it with oil. Replace the cap and rotate the tin slowly, ensuring that the oil covers all areas inside the tin. Empty the tin into the bucket.

Caution — when rinsing, do not shake the tin as foaming may occur. This will have an adverse effect on the test results, particularly the DGA and possibly the DS if tested soon afterwards.

i. Hold the tube in the neck of the tin and while avoiding foaming, fill the tin until the oil overflows. The tube shall not touch the oil at any stage.

ii. Place the tin on a flat surface and squeeze the sides very slightly until oil overflows. Replace the cap firmly before releasing the pressure.

iii. With the tin upside down rotate the tin slowly while holding it close to the ear to listen for bubbles resulting from incomplete filling. Retake the sample if bubbles are heard.

iv. Ensure that samples arrive at the laboratory within one week.

A.3.4 On-load tap changer selector switch sampling

Caution — Samples shall only be taken from the transformer selector bottom valve. Furthermore, the selector switch shall only be sampled to confirm the originality of the fault that exists in the power transformer tank. This assumes that the valve between the selector switch and the main tank is opened during the operation of the power transformer.

Sampling of the tap selector switch assumes that the valve between the transformer main tank and the selector tank is closed segregating the main tank oil from the tap changer selector oil. This scenario is normally the case when there is a need to determine the origin of the fault in the transformer tank.

a. Open the cap of the sample tin and inspect the inside of the tin for dirt and rust

Appendix A
(Concluded)

b. Fill the sample oil sample label accurately and correctly. Then stick it onto the side of the sample tin. Record the loading of the power transformer on to the oil sample label

c. Remove the plug and clean the tap changer selector switch valve with a chamois cloth. Then fit the house coupling and hose on to the selector switch valve.

d. Open the tap changer selector switch valve and allow approximately 2 litre of oil to run vigorously into the bucket

e. Adjust the flow of oil to a medium rate. Do not operate the valve again until oil sampling is complete.

f. Fill half of the sample tin with oil. Replace the cap and rotate the tin ensuring that the oil covers the entire inside of the tin

g. Empty the oil in the sample tin into the bucket

h. Repeat step (f) and (g) twice to ensure that all the dirt in the sample tin are removed

i. Fill the sample tin by holding the hole in the neck of the tin to avoid foaming and touching the tin. Tilt the sample tin so that the opening is at the highest point. Fill the sample tin until it overflows to allow all the air bubbles to escape. Rinse the cap to ensure that no impurities or bubbles are trapped

j. Place the tin on a flat surface and slightly depress the sides of the sample tin inwards to allow slight overflowing of oil. Then replace the cap. Check that no air is trapped inside the sample tin by rotating it slowly close to ones ear. If air is present it will be clearly heard and start again from step (f). Use your intuitive observation to check if the oil flow rate is not excessively high.

k. Place the sample tin into the secure box for transportation and delivery to the oil laboratory.

l. Ensure that the oil sample arrives at the oil laboratory within five days after taking the sample

m. The check the oil level indicator on the conservator tank and according to the name plate. The oil level is acceptable if it is between 1/3 and 1/2 full. If not, then the conservator tank needs to be topped up. Topping up should be performed according to the procedure. It is the oil sampler's responsibility to notify the responsible person that the specific transformer requires to be topped up.

n. Replace all the parts of the transformer that were removed and clean the surrounding area of any oil droplets

o. The waste oil in the bucket must be poured into the used transformer oil drum at the depot and may not be reused. This oil will be sent away for regeneration once the drum is full.

A.3.5 Using the on-line dissolved gas analyser sample point

When taking an oil sample from a transformer fitted with a True Gas dissolved gas analyser, the sample shall be taken at the valve provided on the inlet side of the on-line analyser. The drain valve is not to be used as a sample point in this instance.

APPENDIX B – OIL SAMPLE LABEL

(Normative)

(Minimum Requirements)

ESKOM OIL SAMPLE LABEL

Reason for sampling
……
……
……
……
……

Business Unit .....
District .....
Station .....

Bay……
Manufacturer ……
Transformer Oil Volume…….…….…….…… (i)
Year of Manufacture ……
Serial Number……..……
Rating ……. (MVA)
Highest Voltage …… (kV)
Top Oil Temp. (OTI)…….. (˚C)

Sampling point		
	Transformer	
	Diverter	
	Other	

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

Notes

Bay — Give unit bay designation (i.e. Unit Bay 2)

Sampling point:

Transformer - Mark this box if the sample is taken from either the Main Tank or the Buchholz and specify which of the two in the blank space.

Diverter - Mark this box if the sample is taken from the on-load tap changer diverter conservator or drain valve, and specify which of the two in the blank space.

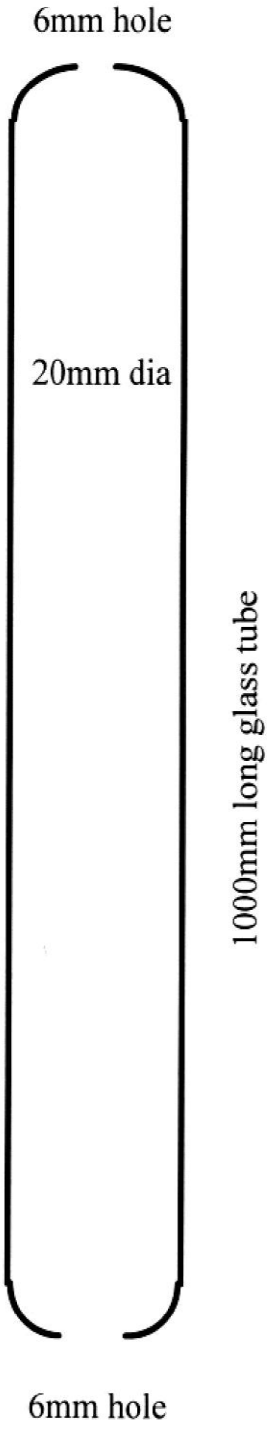
Other - Mark this box if a special sampling point has been requested and fill in which sampling point has been used in the blank space.

APPENDIX C – DRUM SAMPLER AND ITS USE
(Normative)

Oil Thief

The Oil Thief is an oil sampling device which is used for the sampling of oil from drums or similar containers.

It is basically a glass tube (1m long with a diameter of 20mm) with a 6mm hole on each end of the tube.



Procedure:

The tube is placed vertically inside the oil container (with the one open end at the bottom).

Oil will fill the inside of the tube through the bottom hole.

Close the top opening and remove the tube from the container.

Place the bottom opening in the precleaned sample tin.

Open the top hole and allow the oil to flow out of the tube, filling the sample tin. (The normal sample procedure must be followed)

Availability of Oil Thief:

Any glass blower may maufacture the device or contact TRI oil laboratory in Brackenfell (Vickey Hollier tel.021 9803342) for assistance.

APPENDIX D – SYRINGE SAMPLING

(Normative)

D.1 Requirement: The syringe sample shall be taken by a trained and accredited person

1. Sampling point

The oil sample shall be taken from the Main Drain Valve or Bottom Main Tank Sampling Point, via a modified valve blank plate, adapted to suit the three way valve utilised in the syringe sampling procedure.

2. Modification

The Drain Valve blanking plate shall be modified to accept the tygon tube for the three way-sampling valve. A 50 ml glass syringe shall be used together with a three way valve and a length of tygon tubing, leading to an excess oil container.

3. Protection

The syringe shall be supplied in a light protected case and treated with care.

4. Other important considerations are:

i. The power transformer shall be under positive pressure.

ii. Allow at least 2 litres of oil to flow through the sampling valve to thoroughly flushed and cleaned the valve prior to sampling.

iii. No air bubbles should be trapped in the syringe.

iv. The sample syringe shall be kept out of direct sunlight and protected from severe ambient temperatures.

D.2 Procedure:

a. Remove the Drain Valve blanking plate, previously modified to accept the tygon tube for the three way sampling valve.

b. Clean the inside of the main tank drain valve with chamois leather and replace the blanking plate.

c. Flush out at least two litre of oil through the Drain Valve, via a length of hose to the waste oil container. Close the Main Drain Valve. Remove the length of hose.

d. Attach one end of the tygon tube to the blanking plate adapter and the other end to the three way sampling valve, which is in the totally closed position.

e. Lead a second tygon tube from the three way valve waste position to the waste oil container.

f. Open the Main Drain Valve.

g. Open the three way valve to the waste position allowing a steady flow of oil to the waste container.

h. Connect the syringe to the three way valve. The plunger of the syringe should be in the fully depressed position.

i. Change the oil flow from waste to syringe, by adjusting the three way valve. Exercise caution – by guiding the syringe plunger, while the syringe fills to around 10 mL with oil under gravity.

j. Adjust the three way valve to waste – while continuing to support the syringe.

k. Remove the syringe taking care not to allow any movement of the plunger.

Appendix D
(Concluded)

l. With the syringe in a vertical position, depress the plunger to expel all the oil.

m. Refit the syringe to the three way valve.

n. Slowly adjust the three way valve so that the syringe is filled to the 90 mL mark under gravity.

o. Adjust the three way valve to waste.

p. Carefully remove the syringe and taking care not to introduce any air, expel some small quantity of oil and fit the sealing cap to the syringe.

q. Immediately place the syringe in it's light proof container.

r. The syringe shall be carefully transported to the laboratory as soon as is practical.

s. Close the Main Drain Valve and remove the sampling tubes and three way valve.

t. Cap the sample union on the blanking plate

APPENDIX E – CORRECT DRUM STORAGE METHODS

(Normative)

In order to avoid the ingress of moisture into a drum, it is imperative that the drum be stored in the correct manner. The common areas of storage and the associated pitfalls are listed below:

E.1 Outdoor storage

E.1.1 This is by far the most common storage place for oil drums. However, the drums are usually incorrectly stored lying down with the bungs in the vertical line position. This leads to the drum breathing over a 24 h period, since one of the two bungs is above the oil level. During the day the oil heats up and expands expelling a measure of air. Conversely, at night when it cools down and contracts, the moist night air is drawn in and this will condense on the metal surface inside the drum and droplets of water will fall into the oil. Obviously the greater the extremes in temperature the greater the amount of moist air that will be drawn into the drum.

E.1.2 Drums shall not be stored upright with the “bungs up”. Should it rain then rainwater will be dammed up inside the rim of the drum almost covering the bungs. When the expansion and contraction take place, pure water can be drawn into the drum. This will rapidly spoil that oil. (Refer to fig. E.1).

E.1.3 The correct way to store oil drums outdoors is as described in E.2.2 below.

E.2 Storage under cover

E.2.1 Drums shall not be stored upright with the bungs up. If drums must be stored upright, then they shall be stored upside down i.e. “bungs down”.
E.2.2 The correct way is to store the drums horizontally with the two bungs in more or less a horizontal line position i.e. covered by the oil inside the drum. This will prevent the drum breathing due to any extremes in temperature, which could still be experienced under cover. (Refer to fig. E.2).
Where possible, the drums shall be stored on a raised surface so that when it rains, the rainwater will not dam up against the drum: this will lead to rusting and then leaking of oil from the drum. Usually, wooden strip 100 mm × 20 mm laid end to end on the ground, provide a very good means of protection against this. The wooden strips are commonly known as dunnage.

Appendix E
(Continues)

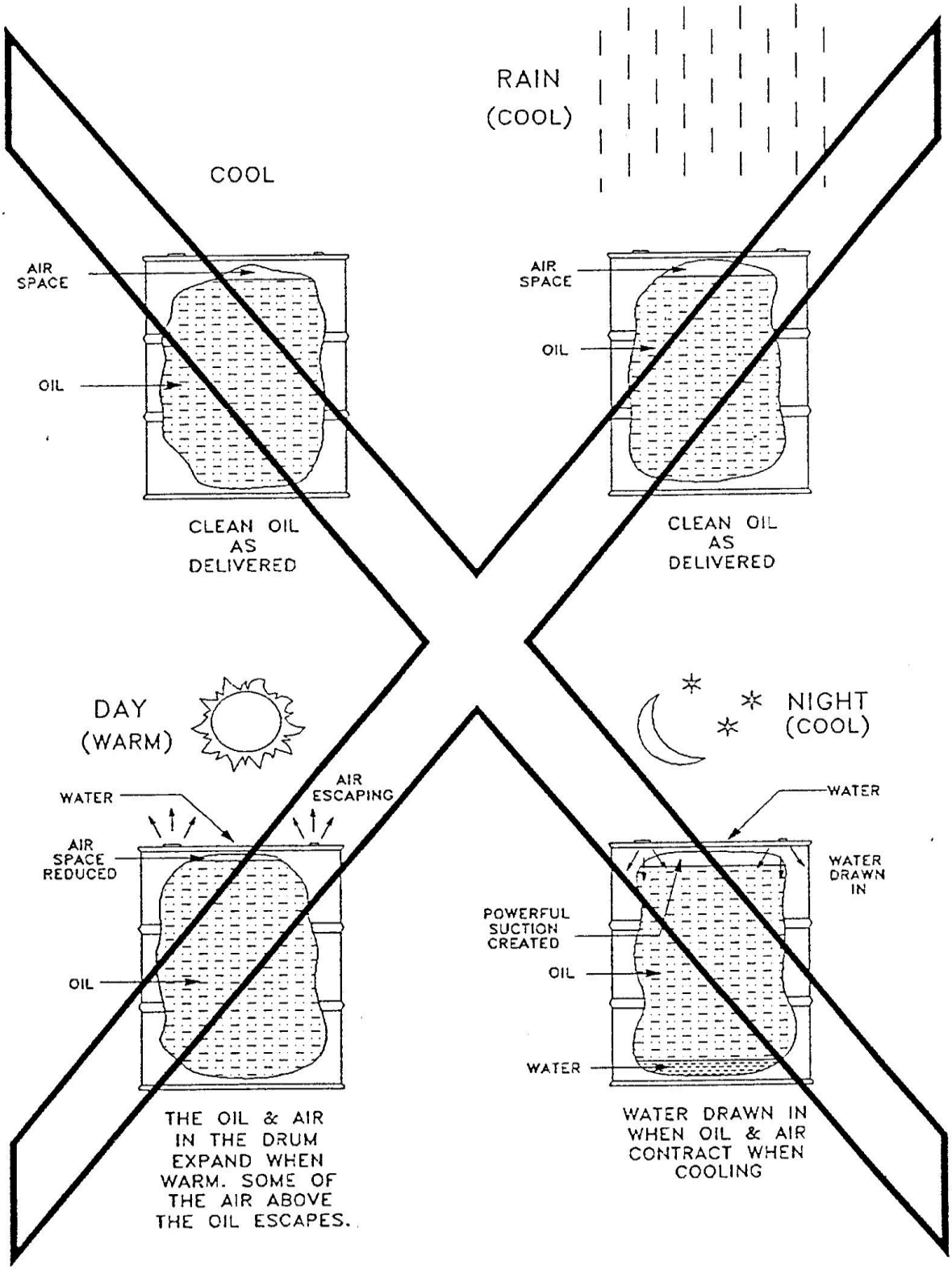


Figure 1: — Incorrect storage of drums Breathing of moisture by an upright drum

Appendix E
(Concluded)

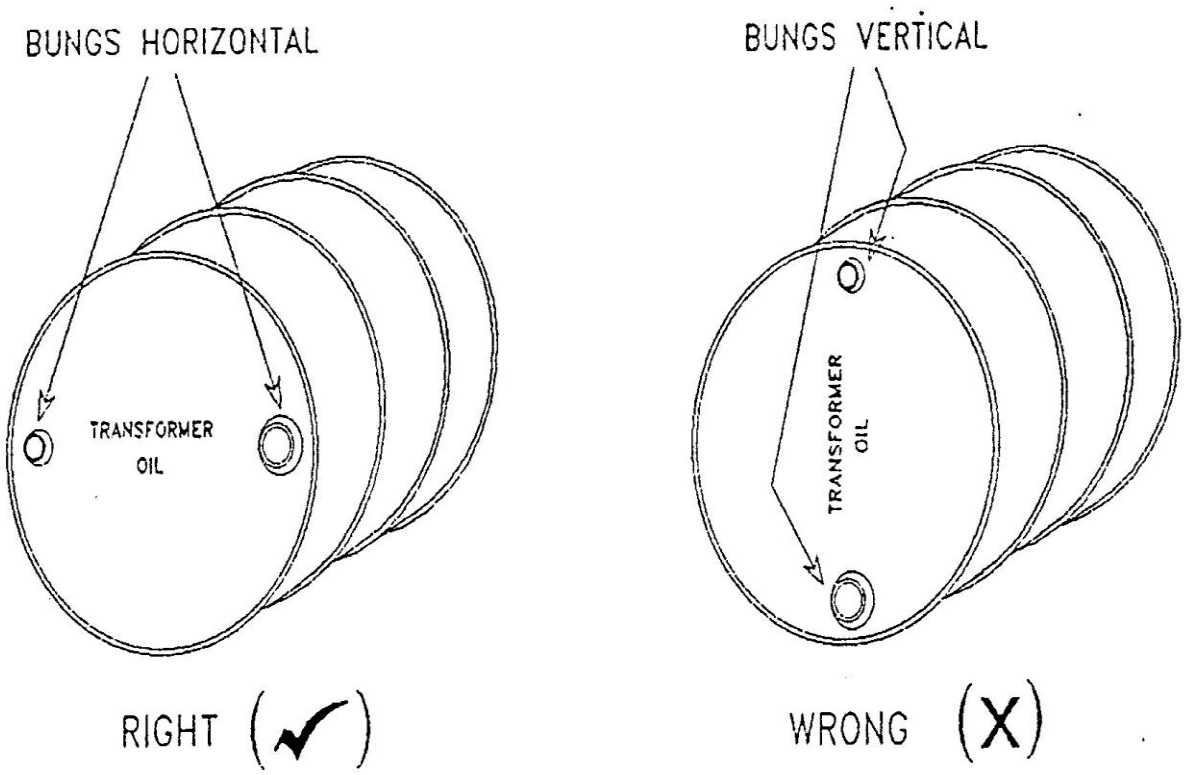


Figure 2: — Horizontal storage position

APPENDIX F – INFORMATION REGARDING OIL FILLING

(Informative)

Caution

1. Oil filling shall only be performed by or under the supervision of transformer system engineer using the manufacturer's filling procedure and specifications.
2. The information below is for information only, and not a procedure to be followed.

F.1 Transformers with MVA rating less than 2MVA

Transformers, which are small enough that, when fully prepared in the factory, the total weight falls within normal transport limits, must be delivered to site ready for service. A 24 h settling time is necessary before the unit is energized. Breather pipes on these units are blanked off and breathers must be fitted on arrival at site.

F.2 Power transformers with MVA rating from 2 MVA but less than 45 MVA

Transformers bigger than those mentioned in F.1, where, when fully prepared, the total weight is such that they no longer comply with normal transport requirements, must be fully prepared in the factory with only the windings covered with oil to reduce the weight for transport.

The oil can then be topped up on site before the unit is ready for service. These units are normally filled from oil in drums that are delivered with the unit. Full preparation must be done timeously and the necessary breathers fitted.

Where drums are used for filling, the seals of the bungs should be examined on delivery to ensure that they are intact. When a cold drum is taken into a warm room, or vice versa, moisture tends to condense on the metal. The seal should not be broken until the condensed moisture has evaporated, and equilibrium reached with ambient temperature.

Fill only to the level indicated by the manufacturer for cold oil, remembering that expansion with temperature will cause the oil level to rise. After filling, a minimum 24 h settling time is required before the unit is energized.

F.3 Power transformers with MVA rating from 45 MVA and above

Transformers which are so large, that, when any oil is added, the total weight of the unit will exceed normal transport requirements must be fully prepared in the factory and delivered to site without oil, but under positive nitrogen pressure. The oil will be supplied in mobile tankers. The unit must then be prepared on site and oil-filled under vacuum.

The oil in the unit must be filtered to get rid of loose cellulose fibres and possible moisture contamination. The oil must meet the desired specification (DS ≥ 70 kV/2,5 mm gap and WC ≤ 10 mg/kg at ± 20 °C) approximately 1 week (7 days) after the oil treatment process has been stopped. This is important since a "wet" condition of the paper insulation is often disguised by the fact that the moisture in the paper takes approximately 7 days at ± 20 °C to reach an equilibrium state with the oil.

Therefore, oil dried on site in the unit will appear dry immediately after the treatment process is stopped and yet, when a sample is taken days later it may be unacceptably wet.

APPENDIX G – ON-SITE DIELECTRIC STRENGTH TEST PROCEDURE

(Normative)

Caution — This procedure shall only be carried out in an environment, which is dust- and moisture-free.

G.1 Test instrument

The test shall be performed using a standard test set for DS testing, such as the Baur or similar instrument. The test shall be carried out strictly in accordance with the operating instructions and testing procedure of the specific instrument used.

G.2 Sampling care

The DS of transformer insulating oil is exceptionally sensitive to the slightest contamination by foreign fluids, material particles, dirt, water, and in particular, fibres. The importance of careful sampling, with special reference to possible absorption of humidity, cannot be over emphasized. Samples of insulating oil for dielectric strength tests shall only be taken by, or under the immediate supervision of, persons of proven judgement, skill and experience in the handling of transformer insulating oils.

G.3 Condition of the oil

The test shall be carried out on the oil as received, without drying or degassing.

G.4 Test cell

The test cell, made of glass or plastic, shall be transparent and have an effective volume of between 300 ml and 500 ml. It shall preferably, be closed (refer fig. F.1).

G.5 Electrodes

The electrodes shall be manufactured from either copper, brass, bronze or stainless steel, and the surfaces shall be polished. They shall be tubular in shape and fitted with rounded end caps, all to the dimensions given in fig. F.1. The electrodes shall be mounted in a horizontal axis with the end caps 2,5 mm apart. The gap between them shall be set to an accuracy of ± 0,1 mm using thickness gauges.
The electrodes shall be replaced as soon as pitting, caused by discharges, is evident.

G.6 Preparation of the cell

Before the cell is used, it shall be thoroughly cleaned, especially if it has not been used for some time. The electrodes shall be removed, cleaned and re-installed, taking extreme care to avoid any direct contact with hands and fingers. When finally assembled, the apparatus shall be rinsed with clean, dry, new oil.

Immediately before use, the cell shall be rinsed (several times if possible) with the oil to be tested. The cell is now ready to be filled with the test sample.
When the cell is not in use, it shall be filled with clean dry new oil and stored in a cool dry place, and protected from dust.

Appendix G
(Concluded)

G.7 Preparation of the sample

The vessel containing the test oil shall be gently agitated and turned over several times in such a way as to ensure, as far as possible, a homogeneous distribution of the impurities contained in the oil without causing frothing and the formation of air bubbles.
Immediately after agitation, slowly pour the sample into the test cell, again avoiding frothing and the forming of air bubbles.
The oil temperature at the time of the test shall be the same as that of the ambient air, preferably within the range of 15 °C to 25 °C.

G.8 Test method 1 (preferred)

This test method consists of applying an increasing a.c. voltage of frequency 40 Hz to 62 Hz (c/s) to the electrodes. The rate of increase in voltage shall be regular and in equal steps of 2 kV/s, starting from 0 and up to the value which produces breakdown.

The breakdown voltage is the voltage reached during the test when the first spark occurs between the electrodes, whether it be transient or established.

The test shall be repeated 6 (six) times on the same cell filling.

The first application of the voltage shall be as quick as possible after the cell has been filled, provided there are no longer any air bubbles in the oil, and at the latest 10 (ten) min. after filling. After each breakdown, the oil shall be gently stirred between the electrodes. For the 5 (five) subsequent tests, the voltage shall be re-applied 1 (one) min after the disappearance of any air bubbles that may have been formed. If the disappearance of air bubbles is not visible, it is necessary to wait 5 (five) min before the next breakdown test is started.

The DS shall be the arithmetic mean of the 6 (six) results which have been obtained.

G.9 Test method 2 (alternative method when using 60 kV testers)

This method consists of applying an increasing a.c. voltage of frequency 40 Hz to 62 Hz (c/s) to the electrodes. The rate of increase in voltage shall be regular and in equal steps of 2 kV/s, starting from 0 and up to 60 kV.

Hold voltage at 60 kV for 1 (one) min.

If no breakdown occurs, the oil shall be considered safe for use in transformers with a maximum voltage up to 132 kV.

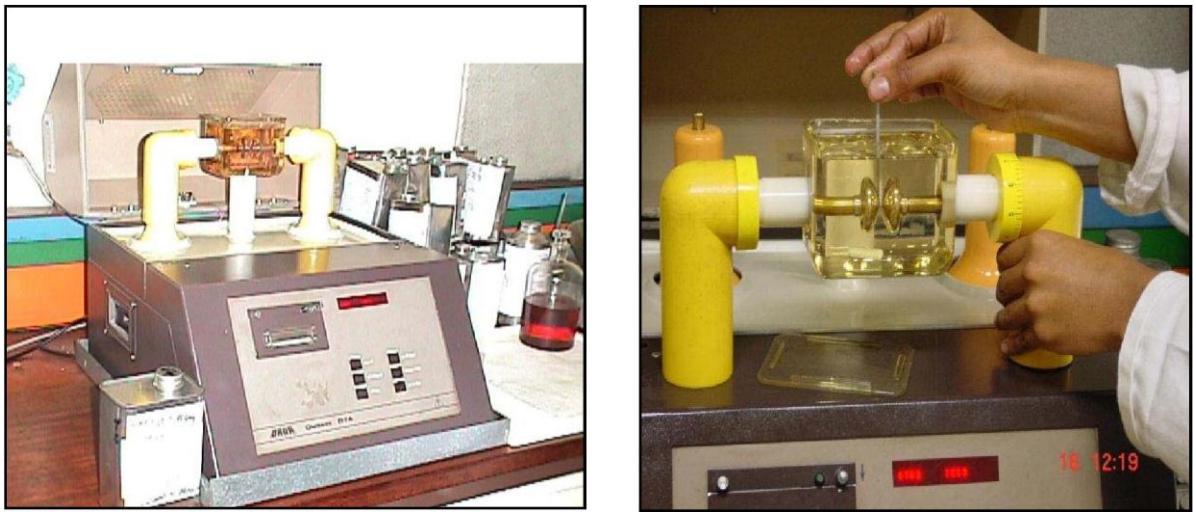


Figure 3: — Typical dielectric strength test cell

APPENDIX H- OIL TESTING AND DISSOLVED GAS ANALYSIS INFORMATION

(Informative)

Caution — this is not a procedure for interpreting dissolved gas analysis tests. It is included for general information purposes only. Interpreting the gas analysis results is not an exact science, mainly because of the influence of the many transformer designs.

H.1 Transformer Oil Gas Analysis

Dissolved gas analysis is a valuable technique for detecting and identifying faults occurring within transformers and reactors. Heat, and/or electrical discharges occurring inside the unit lead to the decomposition (breakdown) of the insulating oil and other insulating materials (paper, barrier board, resin, etc.). Slow generation of gas may allow absorption into the oil whereas a sudden large release of gas will not dissolve in the oil and this will cause the Buchholz relay to activate.

H.2 Gas Chromatography

By separating and quantifying (measuring) the gases found dissolved in the oil the specialist can identify the presence of an incipient fault (early warning).

The amounts and types of gases found in the oil are indicative of the severity and type of fault occurring in the transformer. Note that the rate of gas generation is one of the most important variables and this obviously requires more than one sample to be taken at a specified interval.

It is important to note that the results are generally given as a concentration per oil volume and that the total oil volume is therefore important.

The separation, identification and quantification of these gases require the use of sophisticated laboratory equipment and technical skills and can therefore only be conducted by a suitably equipped and competent laboratory.

The key gases produced are:

- Hydrogen H_2
- Methane CH_4
- Ethane C_2H_6
- Ethylene C_2H_4
- Acetylene C_2H_2
- Carbon Monoxide CO
- Carbon Dioxide $C0_2$

Other higher hydrocarbon gases are produced but these are not generally considered when interpreting the gas analysis data.

Appendix H
(Continues)

H.3 Origin Of Gases In Transformer Oil

Fault gases are caused by corona (partial discharge), thermal heating (pyrolysis) and arcing.

i. Partial discharge is a fault of low-level energy that usually occurs in gas-filled voids surrounded by oil-impregnated material. The main cause of decomposition in partial discharges is ionic bombardment of the oil molecules.

   The major gas produced is hydrogen. The minor gas produced is methane.

ii. Thermal faults. A small amount of decomposition occurs at normal operating temperatures. As the fault temperature rises, the formation of the degradation gases change from methane (CH4) to ethane (C2H6) to ethylene (C2H4).

   A thermal fault at “low” temperature (< 300 °C) produces mainly methane and ethane and some ethylene.
   A thermal fault at “higher” temperature (> 300 °C) produces ethylene. The higher the temperature becomes the greater the production of ethylene.

iii. Arcing is a fault caused by high energy discharge.

The major gas produced during arcing is acetylene. Power arcing can cause temperatures of over 3 000 °C to be developed.

NOTE — If cellulose material (insulating paper, etc.) is involved, carbon monoxide and carbon dioxide are generated.

A normally ageing, conservator type transformer should have a CO2/CO ratio of about 7. Any CO2/CO ratio above 11 or below 3 should be regarded as perhaps indicating a fault involving cellulose provided the other gas analysis results also indicate excessive oil degradation.

H.4 Acidity or Neutralisation Value

Acids in the oil originate from oil decomposition/oxidation products. Acids can also come from external sources such as atmospheric contamination.

An increase in the acidity is an indication of the rate of deterioration of the oil with SLUDGE as the inevitable by-product of an acid situation which is neglected.

H.5 Water Content

Water accelerates the deterioration of both the insulating oil and the insulating material (paper etc.) and more water is produced during this process. This is a never-ending circle and once the paper has been degraded it can never, unlike the oil, be returned to its original condition. Oil saturated with water has an unacceptable low dielectric strength. Water combined with particles and/or cellulose fibres has the same effect, even before the saturation point is reached.

Appendix H
(Concluded)

H.5.1 Origins of water

Water can originate from two sources.

a. Atmospheric

   i. Through the silica gel breather (dry silica gel is always blue).

   ii. Through air leaks into the conservator (e.g. inspection covers open or deteriorated gaskets in the air space of the conservator).

b. Internal sources

   i. Paper degradation produces water.

   ii. Oil degradation produces water.

   iii. Wet insulation acts as a source of water in the oil (temperature-dependent).

H.6 Dielectric Strength

The dielectric strength of insulating oil is a measure of the oil's ability to withstand electrical stress without failure.

Contaminants such as free water, sediment and conducting particles reduce the dielectric strength of insulating oil.

Combinations of these tend to reduce the dielectric strength to a greater degree.
Clean, dry oil has an inherently high dielectric strength but this does not necessarily indicate the absence of all contaminants. It may merely indicate that the amount of contaminants present between the electrodes at the time of the test is not large enough to affect the average breakdown voltage of the liquid.

H.7 Interfacial Tension

The Interfacial Tension (IFT) measures the tension at the interface between two liquids (oil and water) which do not mix and is expressed in mN/m or dynes/cm.

This test is sensitive to the presence of oil decay products and soluble polar contaminants from solid insulating materials.

Good oil will have an interfacial tension of between 40 mN/m to 50 mN/m. Oil oxidation products lower the interfacial tension and have an affinity for both water (hydrophilic) and oil. This affinity for both substances lowers the IFT. The greater the concentration of contaminants, the lower the IFT, with a badly deteriorated oil having an IFT of 18 mN/m or less.

NOTE — In this annex the symbol mN/m represents milliNewton/metre

APPENDIX I – SANS 555 TESTS REQUIREMENTS

(Informative)

Table J.1 — Test requirements SANS 555

			Typical	
TEST	**Method**	**SANS 555 limits**	**Used oil**	**After refining**
Density @ 20 °C kg/l	IP 60	0,895 max.	0,873	0,875
Kinematic Viscosity @ 40 °C mm^2/s	IP 71	16,5 max	12,5	12,4
@ –15 °C mm^2/s		800 max.	330	328
Flash point °C	IP 34	140 min.	150	153
Pour point °C	IP 15	–21 max.	–33	–33
Neutralisation value mg KOH/g	IP 1b)	0,03 max.	0,53	0,01
Corrosive Sulfur	IP 315	Non corrosive	Non corrosive	Non corrosive
ElecTSIc strength kV	IP 295	30 min.	16	72
Resistivity @ 20 °C GΩm	ASTM D1169	-	2	15 000
Resistivity @ 90 °C GΩm		-	0,1	450
Dielectric dissipation factor @ 90 °C	IEC 60250	0,005 max.	3,5	0,0018
Water content mg/kg	ASTM 1533	35 max.	205	8
Oxidation test Neutralization value mg KOH/g	IP 307	0,4 max.	-	0,21
Sludge %		0,1 max.	-	0,036

Typical

Colour			Red/Brown	Straw
Appearance			Cloudy	Clear
Particles		Nil	Present	Nil
Fibres		Nil	Present	Nil

APPENDIX J – AFTER HOUR EMERGENCY SERVICE

(Informative)

After-hours emergency service for transformer oil analysis

TSI oil laboratory at Rosherville, Germiston.

The Transformer Oil Analysis Laboratory provides an after-hours emergency service.

To make use of the services, give an advance warning of a call-out by paging the emergency number below.

The transformer oil laboratory staff will however, only react upon the arrival of the oil sample at the Technology Group, Rosherville security gate when the security guard on duty will page the analyst on standby. The analyst on standby duty should arrive at the Eskom Enterprise Laboratory Services within half an hour of being paged.

The overtime rates for analysis per sample will be approximately 3 times the normal rate.
Results of the analysis will be available within 2 (two) hours of the sample being dropped off at the security gate.

For any queries, contact A E Lombard at Tel. No. (011) 629-5360/5008 during office hours. The PAX numbers are 8189-5360/8189-5008.
For emergency service, phone 082 554-9150.

APPENDIX K– REVISION INFORMATION

(Informative)

Revision information

DATE	REV. NO.	NOTES
Sept. '93	1	NWS 1076 and EVS 051 (not published) were re-written and published as ESKASAAF1 Rev. 1.
Aug. '98	2	ESKASAAF1 Rev. 1 re-formatted, minor revision were made and 4.1.2.9 added. Annexes H, J, K and L were added.
April '02	0	Complete reproduction of the ESKASAAF1 to suite the generation division requirements only. New document name is: GGS 1026