



**TITLE SPECIFICATION FOR PURCHASE,
MANAGEMENT, MAINTENANCE
AND TESTING OF MINERAL
UNINHIBITED INSULATING OIL**

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INTRODUCTION

City Power makes use of power and distribution transformers in the provision of electricity to its customers. Efficiency and reliability of transformers are critical in terms of meeting statutory Quality of Supply parameters as well as customer satisfaction and cost-effective network operation. Mineral insulating oil plays a crucial role in the performance of transformers, performing the functions of electrical insulation and heat transfer. This document provides the specification on the requirements of both Unused mineral insulating oil (Virgin oil) and recycled mineral insulating oil (regenerated oil).

1 SCOPE

This specification defines City Power's requirements for unused and recycled mineral insulating oil.

NORMATIVE REFERENCES

The following documents contain provisions that, through reference in the text, constitute requirements of this specification. 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 specification are encouraged to investigate the possibility of applying the most recent editions of the documents listed below.

SANS 555, Mineral insulating oil for transformers and switchgear (uninhibited)

SANS 290: 2007, Mineral insulation oils – Management of polychlorinated biphenyls (PCBs)

NRS 079-1, Mineral insulating oils (Uninhibited) Part 1: Purchase, management, maintenance and testing

IEC 61619, Insulating liquids – Contamination by polychlorinated biphenyls (PCBs) – Method of determination by capillary column gas chromatography

IEC 60666, Detection and determination of specified additives in mineral insulating oils

IEC 60296:2020, Provides specifications and test methods for unused and recycled mineral insulating oils

2 DEFINITIONS AND ABBREVIATIONS

The definitions and abbreviations in the above documents shall apply to this specification.

3 REQUIREMENTS

4.1 Standard tests and oil analysis

4.1.1 Tests and analysis

Oil tests are categorized depending on the intention of the test or the analysis. These analyses are described in table 1, and the sample container and volume requirements are given in table 2.

The analysis shown in column 1 of table 1 shall be performed on electrical equipment that contains mineral oil.

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Table 1 — Standard tests and analyses

1 Analysis	2 Test set	3 Recommended method of analysis	4 Subclause (in this document)
Dissolved Gas Analysis (DGA)	1	IEC 60628/ASTM D3612	4.2.1.1
Dielectric strength	1/2/3/4	IEC 60156	4.3
Moisture content	1/2/3/4	IEC 60814 and ASTM D1533	4.4
Acidity	1/2/3/4	IEC 62021-1	4.5
Furanic analysis	2	IEC 61198	4.6
Colour	2/3/4	ASTM D1500	4.7
Dielectric dissipation factor (Tan delta)	2/3/4	IEC 61620 and IEC 60247	4.8
Sediment and sludge	2/3/4	IEC 60422	4.9
Interfacial tension	2/3/4	ASTM D971	4.10
Particle contamination	¾	ISO 4406 /IEC 60970	4.11
Polychlorinated biphenyl (PCB)	¾	EPA 600 or ASTM D4059	4.12
Carbon composition	3	ASTM D2140	4.15
Aromatics	3	ASTM D2140/IEC 60590	4.16
Viscosity	3	ASTM D445/ISO 3104	4.17
Corrosive sulphur	¾	IEC 62535	4.13
Aniline point	3	ASTM D611	4.18
Silicon/silicone	¾	ASTM D6595	4.19
Resistivity	3	IEC 60247	4.20
Inhibitor content/FTIR verification ^a	2/3/4	IEC 60666	
Oxidation stability	3	ASTM D2440/IEC 61125 Method C/ ASTM D2112 (RBOT)	4.21
Flash point	3	ASTM D93 /ISO 2719 (closed cup)	4.22
Density	3	ISO 3675 or ISO 12185/ASTM D1298	4.23
Gassing tendency	3	IEC 60628 Method A/ASTM D2300	4.24
Passivator content ^b	2/3	HPLC method (NT24)	4.25
Pour point	3	ASTM D97	
Polyaromatic hydrocarbons	3	BS 2000/IP 346	
Appearance	¾	IEC 60422	4.7

^aInhibitor content, if added.
^bPassivator content, if added.

NOTE 1 See annex B for an explanation of the test sets.
NOTE 2 Subclause 4.31 refers to the specification requirements.

Table 2 — Sample container requirements

1	2	3
Test set	Description	Minimum sample container required
Test set 1	Routine	1 Litre sampling tin or 1 and 50 mL glass syringe
Test set 2	Age assessment	3 × 1 Litre tins
Test set 3	Initial approval and annual verification tests	2 × 5 L tins (new aluminium containers)
Test set 4	Quality assurance criteria tests (before transfer of oil into oil storage containers (i.e. drums, bags, electrical apparatus, ISO-tanks, etc.)	2 × 1 L sampling tins (new), 2 × 200 mL plastic bottles completely full, 1 × 200 mL plastic bottle 80 % full, 1 × ISO certified clean glass bottle 80 % full

4.1.2 Oil classes

Type U insulating oil: insulating oil without any additives (uninhibited), (coded as U).

NOTE This part of specification does not cover partially inhibited oil (double TOPS type I and IEC 60296 class 2).

5. TESTING AND VERIFICATION

- 5.1 Each batch/lot of Unused and recycled oil delivered shall be tested in accordance with SANS 555 and a test certificate at the time of filling, certifying compliance, shall be provided by the tenderer for acceptance of the unused and recycled oil by City Power.
- 5.2 Each batch/lot of recycled oil collected shall be tested in accordance with SANS 290. A test report shall be submitted to the Laboratory Manager:
- 5.3 All test certificates shall be issued by an accredited oil test laboratory.
- 5.4 All costs associated with the testing described above shall be borne by the tenderer and included in the quoted price of unused and recycled mineral insulating oil. No claims in this respect shall be entertained by City Power.
- 5.5 City Power reserves the right to test any oil supplied in accordance with SANS 555 up to two weeks after delivery. Should the oil fail the tests the entire batch/lot may be returned, at the sole discretion of City Power, to the supplier for further processing at no cost to City Power.
- 5.6 Should any dispute arise between City Power and the tenderer, an independent test authority shall test the oil at the cost of whichever party is proven wrong.

6. IDENTIFICATION

In the case of oil which is supplied in 210 litre drums, the drums shall become the property of City Power. The drums shall not be galvanised on any surface which are in contact with the oil. Vessels that contain oil shall clearly identify, on the vessel, the oil they contain. Although this may not be practical for transformer units that are already in service, new transformers and transformers that will be retro-filled need the insulating fluid to be identified on the equipment. This only applies to volumes of above 5 L.

The sole purpose of identification is to aid the field service personnel to handle the contents in the correct manner and to avoid cross-contamination.

7. PACKING, BULK DELIVERIES AND DOCUMENTATION

- 7.1 It is recommended that oil supplied in drums (210 L) will carry the suggested colours found in the individual supplier's insulating oil drum labelling, identification and storage document. The bulk containers shall comply with the current road regulations (see foreword) and the requirements in SANS 10229-1. See figure 2 for guidance on the tests to be performed on insulating oils and which test set to apply.
- 7.2 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 of the certificate shall be kept for auditing purposes. The certificate shall be kept for 30 years.
- 7.3 The oil supplier shall guarantee that, at the point of loading into dedicated supplier tankers or drums, the oil complies with the requirements for "unused oil" or "recycled oil" as defined in tables 4 for unused oil and in table 7 for recycled oil. This guarantee shall be in the form of a certificate (which will be issued by the supplier), of which a copy shall accompany the delivery note. Records of the certificate shall be kept for auditing purposes.

8. OIL SUPPLIED IN TANKS AND DRUMS

8.1.1 Oil supplied in tankers and ISO tanks

On delivery on-site, and before transfer to containers (i.e. drums, bags, electrical apparatus, ISO tanks, etc.), the oil shall be tested in accordance with test set 4 (see tables 1 and 2).

9. OIL SUPPLIED IN DRUMS

Drums are sealed at the point of loading by the supplier. Oil will comply with tables 5 and 6 and a batch certificate shall be supplied. If the oil has been correctly stored for longer than one week, the oil shall be re-tested for water content and dielectric strength.

10. TRANSPORTATION AND STORAGE

Drums shall be positioned either with the two bungs in a horizontal line position or upside down, i.e. bungs down.

NOTE If there is any doubt about the oil condition, the oil should be tested before use.

11. RECYCLING OF OIL

Only batch regeneration is acceptable. The oil shall be recycled batch-wise to comply in all respects with table 6 or table 7. Oil shall be tested for compliance with the requirements in table 7, with the exception that before use, the oil shall comply with the DS (dielectric strength) and WC (water content) requirements in this part of this specification. Certification of compliance on each batch of oil recycled shall be kept for auditing purposes.

12. ELECTRICAL EQUIPMENT CLASSIFICATION

In order for this part of this specification to be applicable to all electrical equipment in industry, classification of electrical equipment is necessary. The classification shown in table 3 will apply.

Table 3 — Electrical equipment classification

1	2	3
Category	Classification	Recommended Oil
Class A	Power transformers and reactors with a nominal system voltage related voltage where continuity of supply is vital and similar equipment for special applications where equipment is required to operate under onerous conditions.	Uninhibited oil (type U)
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)
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-changer 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)
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 control gear with a nominal system voltage ≤ 11 kV.	Uninhibited oil (type U)

13. OIL REQUIREMENTS BEFORE COMMISSIONING

13.1 Oil can enter the process as unused oil (virgin oil) supplied to a site, or as oil that has been recycled through a regeneration process, or as oil supplied in the equipment when purchased new or after repair. There may be slight differences in the oil in different items of equipment. Recycled oil may contain low levels of PCB since nearly all the oil in South African equipment contains low levels of PCB contamination. New or recycled oil that has been placed in the equipment will contain tiny particles due to exposure to the cellulose insulation. It is hence vital that the various stages of oil life be defined by different applicable criteria. Tables 4 to 7 show recommended limits for the various oil types, given the process background.

14. COMPATIBILITY REQUIREMENTS AND FORMULATION

14.1 The supplier shall notify the asset owner of any significant formulation changes that may affect the insulation or cooling performance or its compatibility with existing equipment or existing insulating oil and describe the nature of the change.

Compatibility testing shall be carried out by the asset owner, if required.

14.2 The supplier shall inform the asset owner of any additives and the nature of the additive in the oil.

14.3 Insulating oil purchasing requirements

Table 4 — Recommended limits for oil properties of new (virgin) oil uninhibited oils (type U)

1	2	3	4
Oil	Unit	Specification	Reference or test method
Oil type		Naphthenic type U	(Type U) uninhibited
Colour	ISO units	≤ 0,5 max.	ASTM D1500
Inhibitor		Uninhibited	IEC 60666
Appearance		Clear, free of sediment and suspended matter	IEC 60422
Density at 20 °C	kg/dm ³	≤ 0,910 max.	ISO 3675/ISO12185/ ASTM D1298
Kinematic viscosity at 40 °C	mm ² /s	≤ 11 max.	ASTM D445/ISO 3104
Furans and furfural	mg/kg	≤ 0,05 max.	IEC 61198
Flash point	°C	≥ 140 min.	ASTM D93/ISO 2719 (closed cup)
Pour point	°C	≤ -20 max.	ASTM D97
Aromatic content	%	6 to 14 max.	ASTM D2140/IEC 60590
Total furfural and furans	mg/kg	0,1 max	IEC 61198
Polyaromatic Hydrocarbons	%	≤ 3,0 max.	BS 2000/IP 346
Aniline point	°C	63 to 84	ASTM D611
Interfacial tension at	mN/m	≥ 40 min.	ASTM D971
Neutralization value	mg KOH/g	≤ 0,01 max.	IEC 62021-1
Corrosive sulphur		Non-corrosive	IEC 62535
Moisture	mg/kg	≤ 10 max. ^a ≤ 20 max. ^b ≤ 10 max. ^{c, d, e, f}	IEC 60814/ASTM D1533
Antioxidant additives	% by mass	No additives	IEC 60666
Oxidation stability acidity after 164 h at 110 °C	mg KOH/g	≤ 0,6 max.	ASTM D2440-2004
Oxidation stability sludge after 164 h at 110 °C	% by mass	≤ 0,3 max.	ASTM D 2440-2004
Dielectric strength	kV/2,5 mm	≥ 70 min. ^a ≥ 60 min. ^b 70 min. ^{c, d, e, f}	IEC 60156
Dissipation factor at 90 °C		≤ 0,005 max.	IEC 61620 / IEC60247
Gassing tendency	mm ³ /min	≤ +5	IEC 60628 (method A)/ ASTM D2300
Maximum particulate contamination per 100 MI	Before filling	≤ 4000 particles > 5 µm ≤ 500 particles > 15 µm or 12/9 (ISO rating) ^c	
Silicon/silicone content	mg/kg	Not detectable	ASTM D6595
Polychlorinated biphenyl	mg/kg	Not detectable	ASTM D4059

^a Before transportation.
^b On delivery.
^c Before filling.
^d After circulation.
^e Before top-up.
^f After dry out.

15. Gas in oil limits

In essence, there should be no gas present in new or recycled oil. When oil is tested for the presence of atmospheric gas, traces of atmospheric gases will be present in the oil. Table 5 below indicates the acceptable limits for all oil returned to service.

16. Recycling of oil

16.1 In the interests of keeping the oil pool's integrity, the following tests shall be applied before the oil is recycled. Oil that does not comply with the limits stated in table 7 shall be disposed of and the disposal procedures in 4.35.2 to 4.35.4 shall be adhered to.

Table 5 - Gas in oil limits

1	2	3
Gas	Symbol	Detected in new oil, in ppm
Hydrogen	H ₂	Non-detectable
Oxygen	O ₂	< 10 000
Nitrogen	N ₂	< 30 000
Methane	CH ₄	Non-detectable
Carbon monoxide	CO	Non-detectable
Carbon dioxide	CO ₂	< 50
Ethylene	C ₂ H ₄	Non-detectable
Ethane	C ₂ H ₆	Non-detectable
Acetylene	C ₂ H ₂	Non-detectable

16.2 Only uninhibited oil shall be used when equipment is being topped up, particularly in equipment that contains new paper insulation.

16.3 Under no circumstances shall PCB values be increased by adding oil with a greater PCB concentration than the existing concentration level in any item of equipment.

16.4 Under no circumstances shall PCB values be allowed to increase in the recycled pool by adding oils of higher PCB concentration than the existing concentration level in the oil pool.

16.5 Under no circumstances shall virgin oil (zero mg/kg PCB) be used to dilute PCB values in contaminated oil. (See SANS 290.)

NOTE Used oil should be disposed of in accordance with the approved commercial processes.

Table 6 — Oil recycled pre-tests

1	2	3	4
Test description	Unit	Specification	Reference or test Method
Polychlorinated Biphenyls	mg/kg	≤ 20 ^{a b}	EPA 600
Silicon contamination	mg/kg	< 3 ^{a b}	ASTM D6595
Foaming	Mm	300/0 mm	ASTM D892-03
Acidity	mg KOH/g	0,3	IEC 62021-1
Polyaromatic Hydrocarbon	%	≤ 3,0 max.	BS 2000-346
Inhibitor content	% by mass	Dependant on type. No additives. Type U or trace amounts of inhibitor type I	IEC 60666
Corrosive Sulphur		Non-corrosive ^c	IEC 62535

^a Before transportation.
^b Before circulation or draining into tankers or oil bags.
^c Older oils may have a corrosive sulphur component that is not removed in the regeneration process. If this is the case, consider adding a passivator.

**Table 7 — Recommended limits for oil properties for recycled oil
(previously uninhibited) (type U)**

1	2	3	4
Oil	Unit	Specification	Reference or test method
Oil type		Naphthenic type U	Uninhibited (type U)
Colour	ISO units	≤ 1,0 max.	ASTM D1500
Appearance		Clear, free of sediment and suspended matter	IEC 60422
Density at 20 °C	kg/dm ³	≤ 0,895 max.	ISO 3675/ISO 12185/ASTM D1298
Kinematic viscosity at 40 °C	mm ² /s	≤ 16,5 max.	ASTM D445/ISO 3104
Flash point	°C	≥ 140 min.	ASTM D93/ISO 2719 (closed cup)
Pour point	°C	≤ -20max.	ASTM D97
Aromatic content	%	6 to 14 max.	ASTM D2140/IEC 60590
Total furfural and furans	mg/kg	0,1 max	IEC 61198
Polyaromatic hydrocarbon	%	≤ 3,0 max.	BS 2000 /IP 346
Aniline point	°C	63 to 84	ASTM D611
Interfacial tension at 25 °C	mN/m	≥ 40 min.	ASTM D971
Neutralization value	mg KOH/g	≤ 0,03 max.	IEC 62021-1
Corrosive Sulphur		Non-corrosive	IEC 62535
Moisture	mg/kg	≤ 10 max. ^a ≤ 20 max. ^b ≤ 10 max. ^c	IEC 60814 / ASTM D1533
Antioxidant additives	% by mass	No additives	IEC 60666
Oxidation stability acidity after 164 h at 120 °C	mg KOH/g	≤ 1,2 max.	IEC 61125 method C ^d
Oxidation stability sludge after 164 h at 120 °C	% by mass	≤ 0,8 max.	IEC 61125 method C ^d
Dielectric strength	kV/2,5 mm	≥ 70 min. ^a ≥ 60 min. ^b	IEC 60156
Dissipation factor at 90 °C		≤ 0,005 max.	IEC 61620 / IEC 60247
Maximum particulate contamination per 100 MI	Before filling :	≤ 4 000 particles > 5 µm ≤ 500 particles > 15 µm or 12/9 (ISO rating) ^c	ISO 4406 (1999)/IEC 60970/ IEC 60422
	On delivery :	≤ 130 000 particles > 5 µm ≤ 16 000 particles > 15 µm or 17/14 (ISO rating) ^b	
Silicon/silicone content	mg/kg	< 3 mg/kg	ASTM D6595
Polychlorinated biphenyl	mg/kg	≤ 20 max. ^a	EPA 600/ASTM D4059

^a Before transportation.

^b Before circulation.

^c Older oils may have a corrosive sulphur component that is not removed in the regeneration process. If this is the case, consider adding a passivator.

^d In the interests of minimizing the polychlorinated biphenyl levels, in the Electricity Supply Industry any oil that is recycled shall have a contamination level of ≤ 20 mg/kg before the regeneration process.

17. Frequency of evaluating oil in service

17.1 Oil in service is subjected to various conditions that range from copious amounts of oxygen in free-breathing equipment, to very high temperatures in heavily loaded equipment, moisture produced by the deterioration of the oil, the presence of cellulose and possible leaks, etc. All these conditions will affect the properties of the oil, rendering regular in-service assessment of the condition of the oil imperative.

17.2 Insulating oil analyses or tests can be classified in accordance with

- a) characterization, which gives parameters that can be used to identify the oil;
- b) determination of the ageing status, which gives parameters relevant to the ageing process;
- c) determination of the dielectric status, which gives parameters used to determine the dielectric safety margin and dielectric characteristics of the insulation spaces; and
- d) determination of the degradation status, which gives parameters relevant to faults, failure and wear in the equipment.

17.3 The classification of various analyses relating to the type of information gained from analyses is shown in table 8.

Table 8 — Classification of various analyses

1	2	3	4
Characterization	Ageing status	Dielectric status	Degradation status
Fluid composition	Free radicals	Water content	DGA
Carbon types	Visible spectrum	Percentage saturation	Extended DGA
Specific gravity	Acidity	Bound water	Furanic compounds
Viscosity	Saponification number	Particle profile	Phenols
Refractive index	Inhibitor contents	Breakdown voltage	Cresols
Permittivity	IFT	Impulse strength	Dissolved metals
PAH content	Infrared spectroscopy	Charging tendency	Particle profile
Inhibitor content	Dissipation factor	Resistivity	
Total sulphur	Resistivity	Dissipation factor	
Corrosive sulphur	Polarization index	Insoluble sludge	
PCB content	Turbidity	Gassing tendency	
BTA content	Insoluble sludge	PD intention voltage	
	Sludge content		
	Oxidation stability		
	Furanic compounds		

17.4 The results shall be interpreted by accredited personnel. The interpretation should be based on best practices for evaluation of trends, characteristic values for specific types of equipment and oil. Results of typically normal, fair or poor analysis results for a specific rating of specific equipment can clarify certain analyses.

17.5 The analyses should be performed to assist with risk minimization and management, and with life cycle analysis. In order to prevent total loss of large or strategic equipment, an ideal situation would be to do continuous monitoring of the equipment by means of on-line monitoring. However, this is a concept that is at its infancy stage, is limited to certain analyses, and is still very costly where it does

exist. The frequency of analyses is thus dependent on equipment type, strategic nature, voltage, construction and service conditions.

17.6 The frequency of testing should increase if certain analyses indicate degradation of the insulation due to reasons such as overloading or faults.

17.7 Due to the sensitivity of the sampling process and analyses, it is recommended that the sampler is accredited to take samples from a transformer (Level 1 basic sampler training) and, quality assurance and specialised sampling (Level 2 advanced sampler training).

Level 1: Sampler attends a one day technical training course and is assessed on sampling technique on the second day. The duration of the course is one and a half days. Level 2: Sampler attends a half day technical training course and a half day assessment. The duration of the course is one day.

17.8 The recommended frequency of insulating oil analyses on electrical equipment (sampling frequency per classification) is shown in table 9.

Table 9 — Recommended frequency of insulating oil analyses on electrical equipment

1	2	3	4	5	6
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	On special Request
Routine tests (test set 1)	6 monthly	6 monthly to Yearly	6 monthly to yearly ^a	Yearly ^a	On special Request
Inhibitor (antioxidant) additive (part of test set 4)	Before filling, 6 months after filling and every 2 years	Before filling 6 months after filling and every 2 years	Before 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, hereafter every two years (if added)	1 week after addition, 6 months to Monitor consumption, thereafter every 2 years (if added)	1 week after addition, 6 months to monitor consumption, thereafter every 2 years (if added)	1 week after addition, 6 months to monitor consumption, thereafter every 2 years (if added)	Not tested
Ageing assessment (add list of tests)	Once a year	Every second Year	Dependent on application	Not tested	Not tested
Special investigations (test set 3)	On special request	On special Request	On special request	On special request	On special Request
<p>^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 economic feasibility studies, but should not exceed a three year interval for this type of equipment.</p>					
<p>NOTE 1 The frequencies in this table refer to a normal routine test programme and if in any of the tests properties indicate significant deterioration, the periods should be shortened accordingly.</p>					
<p>NOTE 2 In the case of a change of oil supplier (more than once), then the oil quality test set should apply after each supplier change.</p>					

18. EVALUATION OF OIL IN SERVICE

It is almost impossible to compile a set of regulations that will be applicable to all equipment. Some equipment is more tolerant of unfavourable conditions, whereas other equipment will be very sensitive. It is always recommended to take a second sample, before taking action, in order to ensure that the results obtained are in actual fact a true reflection of the state of the electrical equipment. The recommended limits and actions for oil in service are shown in table 10.

Table 10 — Recommended limits and actions for oil in service

1 Analysis	2 Class	3 Recommended action limits	4 Recommended action
Breakdown voltage, kV/2,5 mm	O and A	< 60	Re-sample and identify any trend. Recondition oil by means of filtration.
	B	< 50	
	F	< 40	
	C	< 30	
Moisture content, mg/kg or mg/kg (normalized to 20 °C), assuming top oil temperature of 30 °C	O and A	< 7	Re-sample and identify any trend. Moisture assessment recommended. Recondition oil by means of filtration or purification (or both).
	B	< 10	
	F	< 17	
	C	< 20	
Acidity, mg KOH/g oil	O and A	> 0,10	Re-sample and identify any trend. Recondition oil by means of regeneration if IFT, colour and sludge also deteriorate.
	B	> 0,15	
	C	> 0,20	
Passivator	All classes	< 25 mg/kg	The passivator needs to be topped up to 100 mg/kg when the level drops below the prescribed limit.
Antioxidant/Inhibitor	O and A ^a	< 0,1%	The inhibitor needs to be topped up to 0,4 % when the level drops below the prescribed limit.
Furanic analysis, mg/kg per Year	O and A	Increase of > 0,05 and DP < 300	This process cannot be rectified. Conditions such as high temperature, overloading and high oxygen content should be avoided
	B and C	Increase of > 0,05 and DP < 250	
Colour and appearance	O and A	Not clear and free of Visible contamination	Re-sample and identify any trend. Recondition oil by means of regeneration if IFT, acid and sludge also deteriorate.
	B and C		
	F		
Dielectric dissipation factor at 90 °C, 40 Hz to 60 Hz	O and A	< 0,1	Re-sample and identify any trend. Recondition oil by means of regeneration.
	B and C	< 0,2	
Sediment and sludge	O and A	Sediment or precipitable sludge Present	Re-sample and identify any trend. Recondition oil by means of regeneration if IFT, colour and acid also deteriorate.
	B and C	Sediment or precipitable sludge Present	
Interfacial tension, mN/m at 25 °C	O and A	< 22	Re-sample and identify any trend. Recondition oil by means of regeneration if acid, colour and sludge also deteriorate.
	B and C	< 22	
Particle contamination per 100 MI	O and A	Particle size > 5 µm: 32 000 Particle size > 15 µm: 4 000 or ISO 15/12	Recondition oil by means of filtration.
	B and C	Particle size > 5 µm: 130 000 Particle size > 15 µm: 16 000 or ISO 17/14	
Polychlorinated biphenyl, mg/kg	All	> 50 ^b	Dispose of or if an approved process exists then decontaminate ^b and regenerate during repair, and re-use in same equipment. Reclassify after 3 months.

^a Depending on application, class B equipment may be included.
^b See the latest national legislation (see foreword) (SANS 290).

NOTE Classes D, E, G and H will only be tested on inception and after repair; no intrusive testing will be performed.

19. MOISTURE ASSESMENT

19.1 To avoid continuous reference to a graph to correlate the moisture content and temperature, moisture in the oil shall be normalized at 20 °C (this temperature is based on the fact that the diffusion rate of moisture below 20 °C is too slow to reach equilibrium). This will only apply to equipment that contains paper insulation.

19.2 The correction *f* factor can be calculated as per NRS 079, **clause 4.38.2**

20. Roles and responsibilities

20.1 Management shall establish a mineral insulating oil quality management system as set out in the framework in figure 3, clause 6. of NRS 079. The responsibilities of management shall be to

- a) formulate a documented quality policy appropriate to the quality management of mineral insulating oils as delivered, in service, during storage, and at disposal;
- b) document quality requirements;
- c) delegate responsibilities for key functions, including quality assurance, quality control, and health and safety, to accredited staff;
- d) ensure that all staff who work with mineral insulating oil are made aware of the proper handling of oil and the effect of oil on the environment; and
- e) provide resources to ensure a safe and hygienic work environment.

20.2 To ensure that these documents and policies are adhered to, frequent audits shall be carried out.

21. QUALITY ASSURANCE

A quality management plan shall be set up in order to assure the proper quality management of new and recycled mineral insulating oil the during usage, operation, maintenance, and servicing phases. Guidance on the requirements for a quality management plan may be found in the ISO 9001:2015/. The details shall be subject to agreement between City Power and the Supplier

22. ENVIRONMENTAL MANAGEMENT

An environmental management plan shall be set up in order to assure the proper environmental management of the new and recycled mineral insulating oil throughout its entire life cycle (i.e. during usage, operation and maintenance, decommissioning and disposal phases). Guidance on the requirements for an environmental management system may be found in ISO 14001:2015 standards. The details shall be subject to agreement between City Power and the Supplier. This is to ensure that the product created conforms to environmental standards and City Power SHERQ Policy

23. HEALTH AND SAFETY

A health and safety plan shall be set up in order to ensure proper management and compliance of the new and recycled mineral insulating oil during usage, operation, maintenance, and decommissioning phases. Guidance on the requirements of a health and safety plan may be found in OHSAS 18001:2007 standards. This is to ensure that the product conforms to standard operating procedures and City Power SHERQ Policy. The details shall be subject to agreement between City Power and the Supplier.

Specific test sets for testing quality assurance and in-service insulating oil

NOTE The subclauses mentioned in column 4 of the tables in this annex are the subclauses in this part of NRS 079-1.

Table B.1 — Test set 1: Routine (see table 10)

1	2	3	4
Analysis	Test set	Recommended method of analysis	Subclause
Dissolving gas analysis (DGA)	1	IEC 60628/ASTM D3612	4.2.1.1
Dielectric strength	1	IEC 60156	4.3
Moisture content	1	IEC 60814 and ASTM D1533	4.4
Acidity	1	IEC 62021-1	4.5

Number of tests in test set 1 = 4

Table B.2 — Test set 2: LTPHIs (see table 10)

1	2	3	4
Analysis	Test set	Recommended method of analysis	Subclause
Dielectric strength	2	IEC 60156	4.3
Moisture content	2	IEC 60814 and ASTM D1533	4.4
Acidity	2	IEC 62021-1	4.5
Furanic analysis	2	IEC 61198	4.6
Colour and appearance	2	ASTM D1500	4.7
Dielectric dissipation factor (tan delta)	2	IEC 61620 and IEC 60247	4.8
Sediment and sludge	2	IEC 60422	4.9
Interfacial tension	2	ASTM D971	4.10

Number of tests in test set 2 = 8

Table B.3 — Test set 3: Recycled or used oil

1	2	3	4
Analysis	Test set	Recommended method of analysis	Subclause
Dielectric strength	3	IEC 60156	4.3
Moisture content	3	IEC 60814 and ASTM D1533	4.4
Acidity	3	IEC 62021-1	4.5
Colour and appearance	3	ASTM D1500	4.7
Dielectric dissipation factor(tan delta)	3	IEC 61620 and IEC 60247	4.8
Sediment and sludge	3	IEC 60422	4.9
Interfacial tension	3	ASTM D971	4.10
Particle contamination	3	ISO 4406 (1999)/IEC 60970	4.11
Polychlorinated biphenyl (PCB)	3	IEC 60619 or EPA 600 or ASTM D4059	4.12
Carbon composition	3	ASTM D2140	4.15
Aromatics	3	ASTM D 2140/IEC 60590	4.16
Viscosity	3	ASTM D445/ISO 3104	4.17
Corrosive Sulphur	3	IEC 62535	4.19
Aniline point	3	ASTM D611	4.18
Silicon/silicone	3	ASTM D6595	4.19
Resistivity	3	IEC 60247	4.20
Inhibitor content/FTIR verification	3	IEC 60666	4.14
Oxidation stability	3	ASTM D2440/IEC 61125 Method C/ASTM D2112 (RBOT)	4.21
Flash point	3	ASTM D93 /ISO 2719 (closed cup)	4.22
Density	3	ISO 3675 or ISO 12185/ASTM D1298	4.23
Gassing tendency	3	IEC 60628 Method A/ASTM D2300	4.24

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1	2	3	4
Analysis	Test set	Recommended method of analysis	Subclause
Passivator content	3	HPLC method (NT24)	4.25
Pour point	3	ASTM D97	
Aromatics	3	BS 2000-346	4.16
Colour and appearance	3	IEC 60422	4.7

Number of tests in test set 3 = 25

Annexure A - Bibliography

EThekweni Electricity technical specification for regeneration of used insulating oil

Previous GJME specification for regeneration of used insulating oil

Annex B - Revision information

DATE	REV. NO.	NOTES
April 2004	0	First issue
Oct 2008	1	Format changes 4.1.8, f) & g) added All oil supplied to City Power in drums shall be delivered in Class A drums. Any signs of rust on the drums shall be deemed unacceptable and such drums shall be returned to the supplier.
Feb 2011	2	All old oil collected from City Power, in old or damaged drums, for disposal, shall be disposed of in their entirety by the successful tenderer – disposal includes old or damaged drums. Cover paper updated Updating of 4.1.4 and 4.1.6 Inclusion of 4.1.5 Inclusion of 6.4 Edited 7.5 Edited 8. Quality management Edited 9 Environmental management Updated technical schedules
OCT 2020	3	General editing Changed 8 quality management to quality assurance Added SHERQ clauses

Annex C - Technical schedules A and B for new insulating oil

Schedule A: Purchaser's specific requirements

Schedule B: Guarantees and technical particulars of product/services offered

Item	Sub-clause of CP_TSSPEC_116	Description	Schedule A	Schedule B
1	4.1.1	Standard to which new oil complies	SANS 555	
2	4.1.4	Standard to which PCB testing is carried out	IEC 61619	
3	4.1.5	Oil type	Type U Uninhibited	
4		Colour	ISO ≤ 0.5 max	
5		Appearance	Clear, free of sediment and suspended matter	
6		Density at 20°C	Kg/dm ³ ≤ 0,910 max	
7		Kinematic viscosity at 40°C	mm ² /s ≤ 11 max	
8		Furans and fufural	mg/kg ≤ 0.05 max	
9		Flash point	°C ≥ 140 min	
10		Pour point	°C ≤ - 20 max	
11		Aromatic content	% 6 – 14 max	
12		Total fufural and furans	mg/Kg 0,1 max	
13		Polyaromatic hydrocarbon	% ≤ 3,0 max	
14		Aniline point	°C 63 to 84	
15		Interfacial tension at 25 °C	mN/m ≥ 40 min	
16		Neutralization value	mg KOH/g ≤ 0,01 max	
17		Corrosive sulphur	Non-corrosive	
18		Moisture	Mg/kg ≤ 10 max (1) ≤ 20 max (2) ≤ 10 max (3)	
19		Anti-oxidant additives	% by mass No additives	
20		Oxidation stability acidity after 164 h at 120°C	Mg KOH/g ≤ 0,6 max	
21		Oxidation stability sludge after 164 h at 120°C	% by mass ≤ 0,3 max	

(1) Prior to transportation (2) On delivery (3) Prior to filling

Tender Number: _____

Tenderer's Authorised Signatory: _____

Name in block letters

Signature

Full name of company: _____

Annex C - Technical schedules A and B for new insulating oil (Cont)

Schedule A: Purchaser's specific requirements

Schedule B: Guarantees and technical particulars of product/services offered

Item	Sub-clause of CP_TSSPEC_116	Description	Schedule A	Schedule B
22		Dielectric strength kV/2,5 mm	≥ 70 min (1) ≥ 60 min (2) ≥ 70 min (3)	
23		Dissipation factor at 90°C	≤ 0,005 max	
24		Gassing tendency mm ³ /min	≤ +5	
25		Maximum particulate contamination per 100ml	Prior to filling ≤ 4000 particles > 5µm ≤ 500 particles > 15µm or 12/9 (ISO rating)(3) On delivery ≤ 130 000 particles >5µm ≤ 16 000 particles >15µm or 17/14 (ISO rating) (2)	
26		Silicon/silicone content ppm	Not detectable	
27		Polychlorinated biphenyl mg/kg	Not detectable	
28	6	Is marking and packing in accordance with clause 6?	Yes/No Yes	
29	7	Is all documentation requested in clause 7 supplied?	Yes/No Yes	
30	8	ISO 9001 accreditation (Quality Management)	Yes/No Yes	
31	9	ISO 14001 accreditation (Environmental Management)	Yes/No Yes	

(1) Prior to transportation (2) On delivery (3) Prior to filling

NOTE: TICKS [✓✗], ASTERISK [*], WORD [NOTED], OR TBA [TO BE ADVISED] SHALL NOT BE ACCEPTED.

Tender Number: _____

Tenderer's Authorised Signatory: _____
Name in block letters Signature

Full name of company: _____

**Technical schedules A and B
Deviation schedule for new insulating oil**

Any deviations offered to this specification shall be listed below with reasons for deviation. In addition, evidence shall be provided that the proposed deviation will at least be more cost-effective than that specified by City Power.

Item	Sub-clause of CP_TSSPEC_116	Proposed deviation

Tender Number: _____

Tenderer's Authorised Signatory: _____
Name in block letters Signature

Full name of company: _____

Annex C - Technical Schedules A and B for recycled insulating oil

Schedule A: Purchaser's specific requirements

Schedule B: Guarantees and technical particulars of product/services offered

Item	Sub-clause of CP_TSSPEC_116	Description	Schedule A	Schedule B
1	4.1.1	Standard to which new oil complies	SANS 555	
2	4.1.4	Standard to which PCB testing is carried out	IEC 61619	
3	4.1.5	Oil type	Type U Uninhibited	
4		Colour	ISO ≤ 1.0 max	
5		Appearance	Clear, free of sediment and suspended matter	
6		Density at 20°C	kg/dm ³ ≤ 0,895 max	
7		Kinematic viscosity at 40°C	mm ² /s ≤ 16,5 max	
8		Flash point	°C ≥ 140 min	
9		Pour point	°C ≤ - 20 max	
10		Aromatic content	% 6 – 14 max	
11		Total fufural and furans	mg/kg 0,1 max	
12		Ployaromatic hydrocarbon	% ≤ 3,0 max	
13		Aniline point	°C 63 to 84	
14		Interfacial tension at 25 °C	mN/m ≥ 40 min	
15		Neutralization value	mg KOH/g ≤ 0,03 max	
16		Corrosive sulphur	Non-corrosive	
17		Moisture	mg/kg ≤ 10 max (1) ≤ 20 max (2) ≤ 10 max (3)	
18		Anti-oxidant additives	% by mass No additives	
19		Oxidation stability acidity after 164 h at 120°C	mg KOH/g ≤ 1.2 max	
20		Oxidation stability sludge after 164 h at 120°C	% by mass ≤ 0,8 max	

(1) Prior to transportation (2) On delivery (3) Prior to filling

Tender Number: _____

Tenderer's Authorised Signatory: _____
Name in block letters Signature

Full name of company: _____

Annex C - Technical Schedules A and B for recycled insulating oil (Cont)

Schedule A: Purchaser's specific requirements

Schedule B: Guarantees and technical particulars of product/services offered

Item	Sub-clause of CP_TSSPEC_116	Description	Schedule A	Schedule B
21		Dielectric strength kV/2,5 mm	≥ 70 min (1) ≥ 60 min (2)	
22		Dissipation factor at 90°C	≤ 0,005 max	
		Maximum particulate contamination per 100ml		
			Prior to filling	≤ 4000 particles > 5µm ≤ 500 particles > 15µm or 12/9 (ISO rating)(3)
			On delivery	≤ 130 000 particles >5µm ≤ 16 000 particles >15µm or 17/14 (ISO rating) (2)
23		Silicon/silicone content ppm	< 3	
24		Polychlorinated biphenyl mg/kg	≤ 20 max	
25	6	Is marking and packing in accordance with clause 6?	Yes/No	Yes
26	7	Is all documentation requested in clause 7 supplied?	Yes/No	Yes
27	8	ISO 9001 accreditation (Quality Management)	Yes/No	Yes
28	9	ISO 14001 accreditation (Environmental Management)	Yes/No	Yes

(1) Prior to transportation (2) On delivery (3) Prior to filling

NOTE: TICKS [✓ x], ASTERISK [*], WORD [NOTED], OR TBA [TO BE ADVISED] SHALL NOT BE ACCEPTED.

Tender Number: _____

Tenderer's Authorised Signatory: _____
Name in block letters Signature

Full name of company: _____

Technical schedules A and B

Deviation schedule for recycled insulating oil

Any deviations offered to this specification shall be listed below with reasons for deviation. In addition, evidence shall be provided that the proposed deviation will at least be more cost-effective than that specified by City Power.

Item	Sub-clause of CP_TSSPEC_116	Proposed deviation

Tender Number: _____

Tenderer's Authorised Signatory: _____
Name in block letters Signature

Full name of company: _____

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Annex D – Stock Items

Material Group: OILS-TX

Item	SAP No.	SAP Short Description	SAP Long Description
1	552	AVS_OIL INSUL NEW (210 L)	OIL, MINERAL, INSULATING, VIRGIN, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN 210 LITRE DRUM. ITEM SPECIFICATION CP_TSSPEC_116.
2	551	AVS_OIL INSUL REGEN NON EXCHANGE (210 L)	OIL, MINERAL, INSULATING, RECYCLED, NON EXCHANGE, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN 210 LITRE DRUM. ITEM SPECIFICATION CP_TSSPEC_116.
3	11900	AVS_OIL INSUL REGEN EXCHANGE (210 L)	OIL, MINERAL, INSULATING, RECYCLED, EXCHANGE, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN 210 LITRE DRUM. ITEM SPECIFICATION CP_TSSPEC_116.
4	1221	AVS_OIL INSUL REGEN NON EXCHANGE (BULK)	OIL, MINERAL, INSULATING, RECYCLED, NON EXCHANGE, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN BULK. ITEM SPECIFICATION CP_TSSPEC_116.
5	1222	AVS_OIL INSUL NEW (BULK)	OIL, MINERAL, INSULATING, VIRGIN, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN BULK. ITEM SPECIFICATION CP_TSSPEC_116.
6	1223	AVS_OIL INSUL REGEN EXCHANGE (BULK)	OIL, MINERAL, INSULATING, RECYCLED, EXCHANGE, FOR TRANSFORMERS AND SWITCHGEAR, SUPPLIED IN BULK. ITEM SPECIFICATION CP_TSSPEC_116.

