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1 SCOPE

This specification, together with the applicable Transformer Data sheet, provides the technical requirements for the design, manufacture and testing of Dry Type Distribution and Power Transformers.

2 CODES AND STANDARDS

IEC 60076-1	Power transformers – Part 1: General
IEC 60076-11	Power transformers – Part 11: Dry-type
IEC 60905	Loading guide for Dry-Type Power Transformers
ANSI C57.12.01	General Requirements for Dry-Type Distribution and Power Transformers including those with Solid Cast and/or Resin-Encapsulated windings
ANSI C57.12.51	Requirements for Ventilated Dry-type Power transformers, 501KVA and larger, three phase with High Voltage 601 to 34,500 Volts and Low Voltage 208Y/120 to 4160 Volts
ANSI C57.12.55	Dry-type Transformers in Unit installations, including Unit Substations – Conformance standard
ANSI C57.12.58	IEEE Standard Guide for conducting a Transient Voltage Analysis of a Dry Type Transformer Coil
ANSI C57.12.60	IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Dry Type Power and Distribution Transformers, Including Ventilated, Solid-Cast and Resin Encapsulated Transformers
ANSI C57.12.91	IEEE Standard Test Code for Dry-Type Distribution and Power Transformers
ANSI C57.12.94	IEEE Recommended Practice for installation, Application , Operation and Maintenance of Dry-Type General purpose Distribution and Power Transformers
ANSI C57.12.96	IEEE Guide for Loading Dry-Type Distribution and Power Transformers
ANSI C57.98	Impulse tests, Guide for Transformers

3 DEFINITIONS

For the purpose of this specification, the following definitions shall apply:

APPROVED/ACCEPTABLE	:	Approved by and acceptable to the Engineer
ANSI	:	American National Standards Institute
BS	:	British Standard
SANS	:	South African National Standards
IEC	:	International Electrotechnical Commission
Dry Type Transformer	:	A transformer in which the windings are in a gaseous or dry compound-insulating medium.
Encapsulated winding Dry Type Transformer	:	A Dry Type transformer having one or more windings encapsulated in solid insulation.
Resin impregnated Dry Type Transformer	:	A form of a Dry-type transformer whose windings have been impregnated with resin, usually by a Vacuum Pressure impregnation process.
Cast resin Dry Type Transformer	:	A Dry-type transformer having the high voltage winding and, optionally, the low voltage-winding cast in epoxy resin.
Vacuum cast coil Dry Type transformer	:	A form of Dry-type transformer having one (usually the high voltage winding) or more windings cast in epoxy in a mould under vacuum.
Ventilated Dry Type transformer	:	Dry Type transformer, so constructed that the ambient air may circulate through its enclosure to cool its core and windings.
QAR	:	Quality Assurance representative; An independent inspection agency appointed by the Engineer.

The following terms are specified in the General Conditions of Contract:

- Anglo American, Company, Contractor, Engineer.

4 REQUIREMENTS

The transformer shall be suitable for operating on the system voltage indicated on the Data Sheet.

The Primary side of the transformer, usually supplied at medium voltage, should preferably be earthed through a neutral earthing compensator and or resistor limiting the

earth fault current to approximately 300 Amps for 10 seconds and the low voltage system should preferably be resistor earthed to limit the earth fault current to no more than 10 Amps continuously. 400 volts and lower systems may be solidly earthed. Particular network configurations may override the foregoing preferences.

4.1 TYPES

The transformer type shall be specified on the Data Sheet and selected from the IEC or ANSI type classifications and definitions, after taking into account service conditions and power ratings. Alternatively, the type to meet the service and operating conditions could be recommended by the manufacturer.

4.2 PREFERRED SIZES

4.2.1 Rated output

The Continuous Maximum Rating (CMR) shall be stated on the Transformer Data Sheet and Rating plate. For Distribution transformers and Power transformers up to 10MVA, the rating shall be chosen from the R10 ISO series, (100, 125, 160, 200, 250, 315, 400, 630, 800, 1 000, etc.). The selected output rating shall be shown on the attached Data Sheet and subsequently on the Rating plate.

4.2.2 Voltage ratio

The no load voltage ratio shall be as shown on the Data Sheet.

4.3 CLIMATIC CONDITIONS

Transformers shall be suitable for indoor, outdoor and underground use and climatic conditions, under the normal service ambient conditions set out in standards such as IEC 60076, except as modified by the requirements set out below:

a. Altitude not exceeding 1 800m, unless specified in the data sheet

b. Maximum ambient air temperature 40°C

c. Daily average ambient air temperature not exceeding 35°C

d. Maximum relative humidity 98%

In any case the minimum Climatic Class shall be C1 and the minimum Environmental Class shall be E2, as per IEC 60076-11, or ANSI equivalents.

4.4 ENCLOSURE

The transformer shall be supplied either without an enclosure or in an IP23 or IP55 enclosure as selected on the Data Sheet.

The enclosure shall be of robust construction and shall have either bolted covers or padlockable doors.

Precautions shall be taken to prevent or limit the harmful effects of condensation.

The transformer, in its enclosure, shall be supplied with a longitudinal skid underbase with hauling eyes or with wheels.

The core and windings shall be securely bolted into the enclosure and lifting lugs shall be fixed to the transformer core. The lifting lugs and their fixings shall have a factor of safety of 10. The lifting lugs shall be suitable for slinging in a mineshaft with the transformer upright or on its side.

No aluminium material or aluminium rivets shall be used in the construction of the enclosure.

The painting specification used by the manufacturer shall be approved.

4.5 CORE AND WINDINGS

The windings shall either be of copper or aluminium, with copper preferred and of a foil winding. If foil winding is not possible, a disc or spiral design may be used if approved.

The winding connection (Vector group) shall be as per Data Sheet.

The Insulation system for the coils shall be either the 200 deg C or 220 deg C, i.e. the limiting temperature of the whole system being the sum of the maximum allowable temperature rise + the maximum ambient temperature + the hot spot allowance in the coil/core. The 220 deg C system should preferably be specified.

The transformers shall be supplied with off circuit tap selection on the high voltage winding of ± 5% and ± 2 1/2% from the nominal tap. The taps shall be selected by bolted links or a padlockable off circuit tap switch.

All external connections to be made to the transformer shall be onto copper, or tinned copper, flags or studs. If any copper to aluminium connections are required, they shall be made by the Vendor / Contractor and be completely sealed.

Full details of the procedure used in copper to aluminium connections shall be submitted to the Engineer.

All connections shall be brazed or bolted with locking plates. No soft solder connections will be permitted.

The core shall be a 3 limb or 5 limb laminated grain-orientated core with clamping bolts not through the core.

The coil clamping shall be arranged to compensate for any shrinkage of insulation, which may occur.

The core shall be treated to prevent corrosion and the Vendor shall provide details of how coils can be replaced if necessary.

4.6 LOSSES

The Transformer shall be a Low temperature rise, energy-efficient, low load loss type. The guaranteed losses, including tolerances, at the design operating temperature and at various load conditions shall be given in the manufacturer's data sheet or specification.

4.7 INSULATION LEVELS AND SURGE PROTECTION

Adequate Insulation protection Margins shall be assured. Protective Ratio (PR) provides a measure of insulation margin of protection against transient overvoltages. That is,

PR = (Transformer Rated Insulation withstand Level) / (Expected Voltage at Transformer)

Three Protection Ratios should be obtained from the manufacturer:

PRL1 = Chopped-Wave Withstand (CWW) : Front of Wave Protective Level (FOW)

PRL2 = Basic Lightning Impulse Insulation Level (BIL) : Lightning Impulse Protection Level (LPL)

PRLS = Basic Switching Impulse Insulation Level (BSL) : Switching Impulse Protective Level (SPL)

CWW, BIL and BSL are obtainable from the manufacturer test data. The sea level rated insulation levels and lightning impulse withstand voltage shall be as per the appropriate standard, IEC or ANSI. Generally the higher Lightning impulse withstand values should be specified, see table 1 for illustration. In all cases the minimum specified value should not be less than the value that would apply to an equivalent oil insulated transformer.

The Manufacturer shall state the Surge withstand capability of the transformer (BSL) against switching surges with sub-microsecond rise times, and test methods and standards used for verifying the stated values.

FOW, LPL and SPL can be obtained from the Surge Arrester data, if fitted on the transformer, or from the distribution network transient response study yielding the expected network surge profiles

It is preferable to fit appropriate Surge Arresters and ensure that all the Protective Ratios are greater than 1.5. The fitted devices shall be fully specified and their specifications shall be included with the Vendor Data Sheet

TABLE 1: INSULATION LEVELS

Highest Voltage Equipment (kV RMS)	Nominal System Voltage (kV RMS)	Rated short duration power frequency withstand voltage (kV RMS)	Rated lightning impulse withstand voltage (kV peak)		
Less than or Equal to:			A	B	C
1.1	0,525 or 0,4	3	-	-	-

3.6	3.3	10	20	40	45
7.2	6.6	22	40	60	75
12	11	28	60	75	95
24	22	50	95	125	150

4.8 TEMPERATURE RISE

The Temperature rise of the windings measured by resistance shall not exceed 80 degrees Celsius (C) over an ambient of 40 degrees C. However, the Temperature Class of the Insulation (IEC) shall be a minimum of Class H and preferably Class C. In ANSI terms, the temperature of the Insulation system shall be a minimum of 200 deg C and preferably 220 deg C. The Vendor shall state and give guidelines on the application of all derating factors, i.e. for Altitude, Ambient Temperature, Cooling and or Enclosure arrangement, etc.

4.9 DERATING FOR ENCLOSURE

Where the transformer is mounted in an enclosure, in the climatic conditions in 4.3, the enclosure temperature rise shall not exceed 60 degrees C. The Vendor shall state and give guidelines on the application of all derating factors, i.e. for Altitude, Ambient Temperature, Cooling and or Enclosure arrangement, etc.

4.10 PARALLEL OPERATION

Should the transformer be required to operate in parallel with existing transformers, the necessary information of the existing transformers to ensure successful parallel operation shall be included in the Data Sheet.

4.11 FLAME RETARDANCE AND TOXICITY

The transformer shall comprise the minimum possible quantity of inflammable organic material.

Manufacturers shall provide the quantity of inflammable material by mass and details of any tests conducted to prove fire retardancy and self-extinguishing properties.

Manufacturers are to provide the details of any products of combustion, which are toxic, and results of tests conducted. Vendors shall be required to submit a full Material Safety Data Sheet (MSDS).

Flame behaviour to be as per appropriate standards, e.g. IEC 60076-11 Class F1 minimum.

4.12 TEMPERATURE INDICATION AND PROTECTION

When required, the transformer windings shall be fitted with winding temperature sensing indicators as indicated on the Data Sheet. The sensors should be located in places/positions that most closely indicate the hot spot temperature of each winding. Sensors/indicators shall have all or some of the following functions, as specified on the Data Sheet:

- Alarm and Trip Set points
- Set points for cooling fan control
- Local temperature indication
- Analogue or Fieldbus output for remote indication or interfacing to PLC/SCADA

4.13 AIR CLEARANCES

Where air clearances exist in cable boxes they shall not be less than the minimum given in Table 3.

TABLE 3: AIR CLEARANCE DISTANCES

	PREFERRED AIR CLEARANCE				
	22 000V	11 000V	6 600V	3 300V	525/400V
Length of insulator	203 mm	178 mm	127 mm	89 mm	25 mm
Phase to earth	140 mm	114 mm	77 mm	64 mm	25 mm
Phase to phase	241 mm	178 mm	127 mm	89 mm	25 mm

	MINIMUM ACCEPTABLE AIR CLEARANCE				
	22 000 v	11 000v	6 600v	3 300 v	525/400v
Length of insulator	203 mm	127 mm	89 mm	51 mm	19 mm
Phase to earth	140 mm	77 mm	64 mm	51 mm	19 mm
Phase to phase	241 mm	127 mm	89 mm	51 mm	19 mm

4.14 CABLE BOXES

Suitable cable terminations shall be made available for the type of cables specified in the Data Sheet. It shall be possible to accommodate cable entry from the bottom, top or sides, although bottom entry is preferred.

The transformer shall be dispatched with the cable termination equipment suitable for cable entry from the bottom, unless otherwise instructed by the engineer.

The clearance in the cable box where used or cable area shall meet the clearances given in Table 3.

LV cable glands shall be approved mechanical glands and shall be mounted on removable gland trays.

For single core cables the gland trays shall be made of non-magnetic material.

An earthing stud connected to the main frame of the transformer and bonded to the enclosure shall be provided in the cable termination areas for earthing the transformer.

Where it is required, the LV side shall be connected by copper work directly to LV switchboard busbars it shall be indicated on the Data Sheet. The exact position shall be approved.

4.15 EARTHING

4.15.1 Transformers having 550 Volt secondaries

Where Neutral Resistive Earthing of the star point is used, a Current Transformer and Neutral Earthing Resistor (NER) shall be provided where called for on the Data Sheet. The current transformer ratio of the ring type protection class current transformer (minimum aperture 30mm, minimum 10VA) shall be chosen and installed so as to ensure that reliable operation of the associated Earth fault relay throughout the relay's setting range whilst maintaining some degree of co-ordination and discrimination with downstream Earth fault protection.

A 16 mm² PVC insulated conductor shall connect the star point to the earthing resistor and pass twice through the current transformer.

A removable gland tray shall be fitted drilled for an approved gland suitable for the cable size as given in the Data Sheet.

The resistor shall comprise four 27-ohm resistance elements, which may be connected, by captive links, to provide a resistance bank of 27 ohms (which would restrict the earth fault current to 10 amps) or 108 ohms (which would restrict the earth fault current to 2,5 amps).

The resistor shall be capable of carrying the maximum earth fault current continuously.

One side of the resistor shall connect to the star point and the other to the system earth mat.

To allow the integrity of the resistor to be monitored the two ends of the resistance bank shall be wired to terminals. A drilled cable gland shall be provided, if called for in the Data Sheet.

4.15.2 Transformers having 400 Volt secondaries

The neutral (star point) on these transformers shall be solidly earthed.

Where called for on the Data Sheet a current transformer shall be fitted so that the conductor connecting the earth mat to the star point neutral bushing passes through the C.T.

The current transformer ratio of the ring type protection class current transformer (minimum aperture 30mm, minimum 10VA) shall be chosen and installed so as to ensure that reliable operation of the associated Earth fault relay throughout the relay's setting range whilst maintaining some degree of co-ordination and discrimination with downstream Earth fault protection.

A removable gland tray shall be fitted and drilled for an approved gland suitable for the cable size as given in the Data Sheet.

4.16 VIBRATION ISOLATION

The transformer shall be provided with vibration isolation from structural parts by the provision of anti-vibration mounting pads

5 QUALITY ASSURANCE PROVISIONS

5.1 QUALITY MANAGEMENT

The Contractor's quality management system shall comply with the requirements of ISO 9001. All volitionary requirements in ISO 9001 shall be mandatory requirements for items supplied against this specification.

6 TESTS AND INSPECTION METHODS

All testing shall be conducted in accordance with the relevant standards.

Routine tests shall normally be sufficient, but evidence of Type Tests shall be required and where special tests are required, these shall be indicated in the Data Sheet.

6.1 ROUTINE TESTS

The following Tests are considered Routine:

- Measurement of winding resistance
- Measurement of voltage ratio
- Check of voltage vector relationship
- Measurement of impedance voltage and short circuit impedance
- Load loss
- Measurement of no-load loss and current
- Separate source voltage withstand test, and Induced over voltage withstand test
- Partial discharge measurement (test limits shall be approved
- Insulation resistances (between Windings, LV Winding to core, HV Winding to core);

6.2 TYPE TESTS

Certified Evidence of the following Type Tests shall be submitted, even if the Type Test is not required for the particular contract.

- Lightning impulse test
- Temperature rise test (if simulated load method is used the method shall be approved)
- Thermal or Climatic proving tests
- Environmental tests

- Fire Resistance test

6.3 SPECIAL TESTS

The special Tests should be selected from the following

- Surge Test with sub-microsecond rise time surges;
- Winding capacitances test, especially important for analysing and estimating transient voltage surge peaks and planning over-voltage protection;
- Zero sequence impedance;
- Measurement of the harmonics of the no-load current;
- Short circuit test;
- Measurement of sound level.

7 MARKING

Each transformer shall carry a metal plate fixed to the transformer core. Where the unit is enclosed the plate shall be visible and legible even without removing the enclosure door or cover and the transformer energised, otherwise a second plate shall be fixed to the outside of the enclosure or cover. The Name plate shall conform to the appropriate standards. The following information shall be displayed on the plate:

- Manufacturer
- Serial number
- Year of manufacture
- Primary voltage and full load current
- Secondary voltage and full load current
- Power Rating
- % Impedance
- Vector Group
- Frequency
- Class of Insulation
- Maximum Temperature rise of winding.

A metal plate bearing a schematic diagram showing the primary and secondary windings and tap positions with their tabulated values shall also be provided.

APPENDIX A: RELATED DOCUMENTS

IEC 60076-1	:	Power transformers – Part 1: General
IEC 60076-11	:	Power transformers – Part 11: Dry-type
IEC 60905	:	Loading guide for Dry-Type Power Transformers
ANSI C57.12.01	:	General Requirements for Dry-Type Distribution and Power Transformers including those with Solid Cast and/or Resin-Encapsulated windings
ANSI C57.12.51	:	Requirements for Ventilated Dry-type Power transformers, 501KVA and larger, three phase with High Voltage 601 to 34,500 Volts and Low Voltage 208Y/120 to 4160 Volts
ANSI C57.12.55	:	Dry-type Transformers in Unit installations, including Unit Substations – Conformance standard
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ANSI C57.12.91	:	IEEE Standard Test Code for Dry-Type Distribution and Power Transformers
ANSI C57.12.94	:	IEEE Recommended Practice for installation, Application , Operation and Maintenance of Dry-Type General purpose Distribution and Power Transformers
ANSI C57.12.96	:	IEEE Guide for Loading Dry-Type Distribution and Power Transformers
ANSI C57.98	:	Impulse tests, Guide for Transformers
SANS 0157	:	Quality systems
SANS 1091	:	National colour standards for paint
CENELEC HD464 S1	:	Dry-Type Power Transformers
ISO 9001	:	Quality management systems

APPENDIX B: RECORD OF AMENDMENTS

Issue 0 : Based upon AAC Specification 514005 (Issue 3)

APPENDIX C: DATA SHEET

TAG NUMBER OF UNIT

1	Number of transformers		
2	Power rating		kVA
3	Phases		3
4.1	Primary voltage		
4.2	Primary Fault Level		
5	Secondary voltage		Volts
6	Enclosure	IP00 / IP23 / IP55	
7	Frequency		Hz
8	Vector Group		
9`	Impulse strength - see table 1		Peak
10	Tapping switch	OFF CIRCUIT TAP SWITCH / BOLTED LINKS	
11	Tappings	-5% -2½% 0 +2½% +5%	
12	Cooling		

Required

Alarm Contacts	N.O	N.C
Trip Contacts	N.O	N.C
Indication • Instantaneous • Maximum	Yes	No
Fan Controller	Yes	No

Remote Transmission	Analogue	Fieldbus

13 Winding Temperature Rise by Resistance

IEC Temp Class of Insulation		ANSI Temp of Insulation System	
C		220 Deg C	
H		200 Deg C	

14 Cable terminations to be provided for:

	Type of cable	Number of cables	Cable cross sectional area mm^2	Cable cores	Type of cable gland
Primary					
Secondary					
Back-up E/F CT					
NER monitor					

15 Dimensional limits (when applicable)

Height		mm
Weight		mm
Depth		mm
Mass		Kg

16 Transport attachments requirements:

Skids	YES	NO
Wheels	YES	NO
Slinging attachment	YES	NO

17 Transformer required to operate in parallel with an existing Transformer? YES | NO

If YES, provide the following information of the existing transformer:

Rated Power		kVA
Rated voltage ratio		
Load loss at rated current on the principal tap connected to the appropriate reference Temperature		Watt
Impendence voltage at rated current (On the principal tapping)		
Diagram of connection, or connection symbol, or both		

18 Tests

Routine tests	Type tests	Special tests

Type Tests

Special Tests

19 Colour of Enclosure

Standard

20 Earthing resistor and E/F CT to be supplied YES | NO

CT Ratio

Earthing resistor connection required	Series 10 amp	Parallel 2,5 amp

21 Declaration of deviations or non-compliance with this specification and IEC 60076-11 or ANSI specifications

Additional information:

Additional Quality Assurance requirements:

APPENDIX D: INFORMATION TO BE SUPPLIED WITH TRANSFORMER TENDERS

Enquiry Number:		Date**:**
TENDERER:		
1	Rated kVA at maximum daily average ambient Temperature at 40°C	kVA
2	Transformer type (cast resin/resin impregnated Dry Type)	3
3	Number of phases	
4	Frequency	50Hz
5	Voltage ratio (no load).	
6	Tappings	
7.	Vector group.	
8	Typical no load loss at rated temperature	Watts
9	Typical load loss at rated temperature	
10	Tolerances on losses	
11.	Total loss at rated current	Watts
11.1	Loss/Load curve	
12	Regulation at 1,0p.f. and rated current	
13	Regulation at 0,8p.f. and rated current	
14	Regulation at 0,4p.f. and rated current	
15	Efficiency at 1,0p.f. and rated current	
16	Efficiency at 0.8p.f. and rated current	
17	Efficiency at 0.4p.f. and rated current	
18	Impedance voltage at rated current	%
19	Reactance voltage at rated current	%
20	Insulation System	Deg C
21	Temperature rise at rated kVA measured by resistance of windings	
21.1	M V windings.	°C
21.2	L V windings	°C
22	Temperature sensing and Protection	

22.1	Temperature Sensor, Type	
22.2	Temperature Indicator	
22.3	Temperature Max Indication	
22.4	Fan Controller	
22.5	Temperature Remote transmission	
22.6	Temperature Alarm set point	
22.7	Temperature Trip Point	
23	Impulse strength of windings.(Primary/ Secondary)	kV peak
24.	Temperature rise of surface of enclosure at rated transformer output	°C
25	Enclosure IP type	
26	De-Rating Factors for the transformer	
26.1	Ambient Temperature	
26.2	Altitude (MASL)	
26.3	Air flow / Cooling arrangement	
26.4	Enclosure: IP00 to IP23; IP00 to IP55; etc	
26.5	Humidity	
27	Mass of transformer core and windings	kg
28	Mass of enclosure and fittings	kg
29	Total mass	kg
30	Mass of flammable material included in total mass	kg
31.	Overall dimensions	
31.1	Length	(mm)
31.2	Width	(mm)
31.3	Height	(mm)
32.	Conductor material used	
32.1	M V winding conductors	
32.2	L V winding conductors	
33	Current density of windings at rated current	

33.1	Primary winding	(A/mm²)
33.2	Secondary winding	(A/mm²)
34	Flux density of core	(Wb/m²)
35	Maximum sound power level measured 1 metre from transformer (at rated load)	(db)
36	Type of winding	
36.1	M V winding	
36.2	L V winding	
37	Air clearances	
37.1	Medium voltage:	
	Length of insulator	
	Phase to earth	
	Phase to phase	
37.2	Low voltage	
	Length of insulator	
	Phase to earth	
	Phase to phase	