Distribution and Power Transformers



MATELEC GROUP

Certificate CH12/1993

The management system of

MATELEC sal

GHORFINE, P.O.BOX:12 – JBEIL -LEBANON

has been assessed and certified as meeting the requirements of

ISO 9001:2008

For the following activities

- **Design, development, production, installation, sales, and servicing of the following:**
  - **Oil type and dry type power and distribution transformers.**
  - **Metal clad and metal enclosed medium voltage switchgear.**
- **Distribution low voltage, power protection and instrument central system switchboards.**
  - **Package outdoor substations for electrical distribution.**
- **Turn key installation for public, private or industrial electrical distribution.**
- **Turn key installation for industrial supervision and monitoring system.**

This certificate is valid from 25 January 2013 until 24 January 2016
and remains valid subject to satisfactory surveillance audits
Recertification audit due before 12 January 2016
Issue 1. Certified since January 2004

Authorised by

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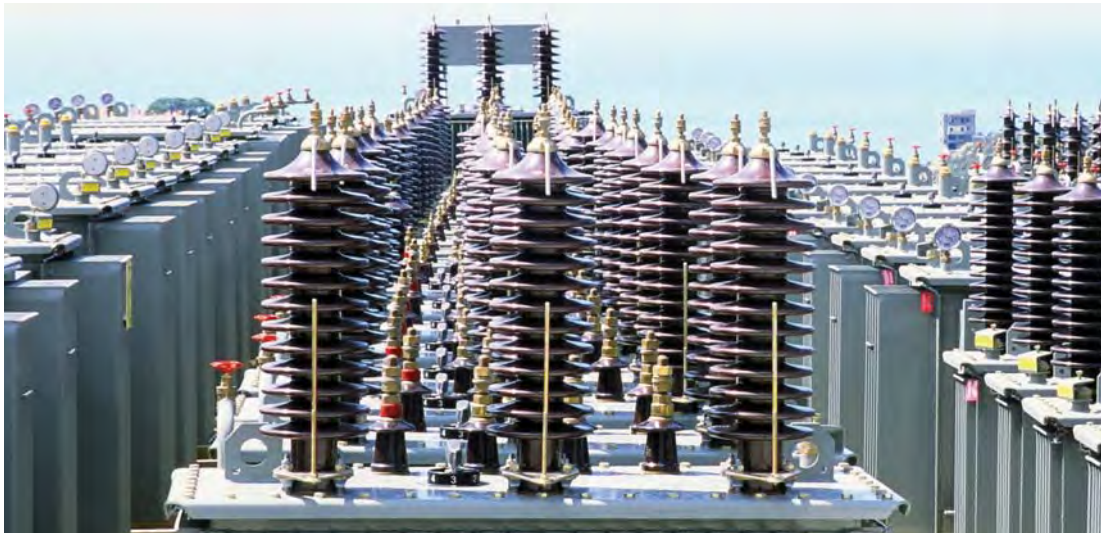

1- INTRODUCTION

A modern industrialized society is totally dependent on electric power. Without it nothing would function. Transformers are the devices that enable us to transmit and distribute electricity over large distances effectively and efficiently. They are essentially static devices which transform the network voltage to a specific different level according to the consumer needs. Transformers are among the primary components for the transmission and distribution of electrical energy.

Matelec Group was founded in 1974 to produce distribution transformers and since then has grown into a diversified and respected electricity business player. Presently, the Group carries manufacturing and commercial facilities across the Middle East, Africa and Europe. The Industrial Division which is involved in the manufacturing of distribution transformers, power transformers, switchgears, panel boards and package substations offers a wide range of efficient, economic and reliable transformers.

The objective of this catalogue is to assist you in defining your needs and optimizing your choices by looking at the characteristics of transformers in a little more detail. In this regard, we will present to you the various design, construction, maintenance and management techniques adopted by Matelec which allow us to manufacture transformers in line with the strictest industry standards.

2- TRANSFORMERS CHARACTERISTICS

2.1. General Characteristics

The transformer design results mainly from:

- Standards,
- Application,
- Installation,
- Insulation liquid,
- Cooling method.

2.1.1. Standards

Many electrical international committees have defined standards for electrical equipment, including transformers.
The IEC, BS, NF and DIN standards are the most applied standards for transformers and for some of their parts.
In every country, the local electric authorities have adopted one of these standards or created one that suits the needs, laws and regulations of their country.

2.1.2. Application

Oil Immersed Distribution transformers

Distribution transformers are the end equipment before electricity reaches the consumer. They provide low voltage by transforming the network medium voltage. In most cases, transformers are designed as liquid filled particularly as oil immersed type.
These transformers have usually a power ranging from 50 to 3150kVA, with a maximum operating voltage of 36kV.

Power transformers

Transformers with higher ratings than 3150kVA are usually classified as power transformers. They are used in the power generation substations and industrial applications. Matelec manufactures power transformers with ratings up to 120000kVA and up to 245kV.

Self-protected liquid-filled transformers

These patented step-down transformers are equipped with a self-protection and disconnection device to protect the environment, property and people and prevent any disturbance of the high-voltage network from the consequences of an internal transformer fault in accordance with IEC60076-13 and with EDF HN 52-S-24. The self-protected transformer may be used in conjunction with other devices to provide system coordination and sensitive system protection. The self-protected step-down transformer is not intended to function in parallel with another transformer.

Other

In addition, there are various special-purpose transformers such as autotransformers, earthling transformers, special power transformers.

Table 1: Transformers data

	Rated Power kVA	Max. Operating Voltage kV
Oil Immersed Distribution Transformers	50-3150	36
Power Transformers	3150-120000	245

2.1.3. Installation

Distribution transformers can be installed:
- Indoor or Outdoor,
- On the Ground or on a Pole.

Power transformers can be installed:
- Indoor or Outdoor,
- On the Ground.

2.1.4. Insulation liquid

Transformers windings should be insulated for electrical withstand by mineral oil (usual application), and optionally by fire resistant oil such as Midel, silicone or FR3.

2.1.5. Cooling method

The identification of oil-immersed transformers according to the cooling method is expressed by a four-letter code. The first letter expresses the internal cooling medium in contact with the windings. The second letter identifies the circulation mechanism for internal cooling medium. The third letter expresses the external cooling medium. The fourth letter identifies the circulation mechanism for external cooling medium.

For example, if cooling method is coded as ONAN (Oil Natural Air Natural), then the internal cooling medium is mineral oil, which is circulated with natural flow, and the external cooling medium is air, which is circulated with natural convection.

Various cooling methods are used including oil circulation by pumps, or forced air circulation by fans, or both of the above. As a result, many cooling methods exist including:
- **ONAF:** Oil Natural Air Forced,
- **OFAN:** Oil Forced Air Natural,
- **OFAF:** Oil Forced Air Forced,
- **OFWF:** Oil Forced Water Forced.
- **ODAF:** Oil Directed Air Forced.

The ONAN/ONAF transformers can be operated ONAN with normal rating and ONAF with an increased rating of approximately 25%.

2.2. Electrical Design

The transformers electrical design results mainly from:

- Power rating,
- Primary and secondary voltage levels,
- Ambient temperature and temperature rise,
- Altitude of installation,
- Short-circuit impedance,
- Vector group,
- No load losses,
- Load losses,
- Frequency,
- Permissible tolerances,
- Other particular conditions.

2.2.1. Power rating

All power ratings are the product of the rated voltage (multiplied by the phase-factor for three-phase transformers) and the rated line current at center tap when several taps are provided. Power rating is expressed in kVA or MVA.
The rated power of the three-phase transformer is defined by the formula:
$P = U I \sqrt{3}$
Where: U is the rated voltage (between phases),
I is the rated line current of the transformer.

2.2.2. Primary and secondary voltage levels

Transformers are energized usually from a network which has a defined voltage level that is, the primary (feed) voltage level.
Transformers should transform the primary voltage to a new voltage, needed by the consumer that is, the secondary voltage level.
Transformers can be designed to operate with two primary voltages (one at a time), thus if the network voltage has to be changed in the future, the same unit will be used. A voltage selector will be the mean to change the primary voltage.
Transformers can be designed to generate two secondary voltages simultaneously, thus outputting two levels for two applications.
The primary and secondary voltages define a Basic Insulation Level (BIL) of 75, 95, 125, 170, 200, 325 & 650kV. The transformer is designed accordingly for electrical withstand of over-voltages.

2.2.3. Ambient temperature and temperature rise

The ambient temperature is the normal ambient temperature under which the transformer will operate.
The temperature rise expresses the rise of the cooling medium and the winding temperatures when the transformer operates at full load. The maximum values are defined by applied standards.

2.2.4. Altitude of installation

The transformers are suitable for operation at altitudes of up to 1000m above sea level. Site altitudes above 1000m require the use of special designs and should be mentioned in the order.

2.2.5. Short-circuit impedance

The short-circuit impedance is the transformer's impedance. Usually between 4% and 6% for distribution transformers and higher than 7% for power transformers, the short-circuit impedance is the percentage of the primary rated voltage that has to be applied at the transformer primary winding when the secondary winding is short-circuited in order to have the rated currents in the primary and secondary windings.
If the short-circuit impedance increases, the voltage drop increases and the short-circuit current decreases.
Transformers working in parallel should have equal short-circuit impedance.

2.2.6. Vector group

The vector group determines the connection of the three phases of primary and secondary windings.
The possible connections are as follows:

- D (d) : delta connection for high voltage (low voltage) winding,
- Y (y) : star connection for high voltage (low voltage) winding,
- Z (z) : zigzag connection for high voltage (low voltage) winding,
- N (n) : the neutral exists in high voltage (low voltage) winding for connection outside the transformer.

The Vector Group also determines the phase displacement between the primary and the secondary winding, each unit in the vector group refers to 30 degrees displacement.
So a vector group Dyn11 is delta on primary, star on secondary, with neutral brought out and 330 degrees phase displacement.
For Autotransformers, Ya0 is the vector group.

2.2.7. No-load losses

The no-load loss is the power consumed in the transformer magnetic core, when the secondary circuit is open.
This is a permanent consumption as long as the transformer is energized.

2.2.8. Load losses

The load loss is the internal power consumption due to the current circulating the windings.
The consumption is proportional to the absorbed power.

2.2.9. Frequencies

The frequency at which the transformer is designed to operate is 50Hz or 60Hz and is set in accordance with the network frequency.

2.2.10. Tolerances

Manufacturing tolerances are the deviations between the measured values and the guaranteed values.
Unless otherwise specified in the order, the tolerances are limited to the values specified in IEC 60076-1.

2.2.11. Harmonic components

An ideal sinusoidal current or voltage is periodic with a fundamental frequency f. In practice, the non-linearity of the transformer core (non sinusoidal flux density distribution) and the implementation of semi-conductor filters in the network, result in a certain amount of energy falling into other frequencies. This spurious energy results in distortion, which is referred to as harmonic distortion.
Harmonic distortion is usually measured in terms of the ratio between the amplitude of the n^{th} frequency component and the amplitude of the fundamental frequency component in percentage.
During installations with considerable converter loading, a conventional rule states that the total deformation of the source shall neither exceed 5% of the total harmonic content nor 1% of the even harmonic content.
In case these values are expected to be exceeded, this should be initially reported by the customer and accordingly taken into consideration in the transformer design.


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Fig 1 – Magnetic circuit

Fig 2 – Step lap

Fig 3 – GT

Fig 4 – Winding coils

2.3. Mechanical Features

2.3.1. Hermetically sealed or breathing tank

For Distribution Transformers, the default construction is the hermetically sealed non-rigid tank completely filled. Air cushion in used with rigid tanks. The variation of oil volume, due to its temperature variation, is absorbed in the flexible fins of the corrugated panels, and in the air cushion when applicable.
Breathing tank with conservator is also a possible configuration.

2.3.2. Tank types

The transformer tank is usually of a non rigid structure with corrugated panels, designed to withstand the mechanical stresses, absorb the oil expansion, and meet the thermal evacuation constraints.
For power rating above 3150kVA, the tank is usually designed with rigid structure, cooling radiators and conservator. Both Conventional and Bell types are available.

2.3.3. Cover

For distribution transformers, covers are made of steel plates with bended edges, thus improving the esthetical aspect and reinforcing the cover which is especially important when untanking the unit.
Accessories are mounted on the cover through adequate connectors. Multifunction holes can be provided to receive different type of accessories.
For example, on the same hole, alternatively a DGPT2 or a pressure relief valve or a thermometer can be mounted.

2.3.4. Magnetic circuit

The magnetic circuit (Fig 1) is of the three legs construction, Step lap (Fig 2) or GT (Fig 3). It is made out of a cold rolled, grain oriented silicon steel strips, each strip (0.23, 0.27 or 0.30mm thick) being insulated from both sides by Carlite.

2.3.5. Winding coils

Both the primary and secondary windings (Fig 4) are made of copper or aluminum. The primary voltage is directly wound on the secondary voltage winding, with insulating barriers and cooling channels between the two windings.
Secondary voltage coils are of rectangular wires or foil conductors. Primary voltage coils are of round enamelled wires, or rectangular paper insulated wires for high power ratings, or round paper insulated wires.
Adequate channels for oil circulation are integrated in the windings to provide an efficient cooling and limit the hot spot temperature.

2.3.6. Cooling liquid

By default, transformer oil according to IEC 60296-03 specifications is used as cooling medium. Other fire resistant insulating liquids with fire points above 300ºC are also available on special request.
For distribution transformers, the primary filling is done under vacuum in order to assure the high penetration of oil. Final filling is made to adjust the appropriate oil level on delivery.

Fig 5 - Shot blasting

Fig 6 - Painting workshop

2.3.7. Painting

Distribution transformers

- First, shot blasting is carried out on tanks and covers according to grade SA2.5 of ISO 8501-1standard in order to remove carbon deposits and all traces of rust (Fig 5)
- This operation is immediately followed by a Zinc phosphate chemical treatment, then by a chromatic passivation made by Chemetall France, applied in a PLC automatic cabin in order to ensure a superior corrosion protection and improve paint adhesion (Fig 7)
- Electrostatic epoxy polyester RAL 7033 powder paint made by Dupont France (designed to reduce Faraday cage effect) is manually applied on the external surface at 10cm from the cover inside the tank, in a powder paint re-circulating cabin (Fig 8)
- Then the tank is heated at 180°C for 15 minutes. The coat paint film deposit is 70 to 100µm (Fig 9)
- An oil resistant paint or varnish could be applied inside the tank if required
- Other paint colors can be provided upon request for large orders

Power transformers

Painting process having a high corrosion and pollution resistance of categories “C5-M” and “C5-I” at high durability (H) according to ISO 12944/5.The different metallic parts are painted in RAL 7033 color according to the following procedures:

- Liquid paint by chemical hardening
- Electrostatic epoxy powder paint

Painting of tank

- First, shot blasting is carried out according to grade SA2.5 of ISO 8501-1 standard in order to remove carbon deposits and all traces of rust
- Internal surfaces are painted with epoxy phosphate of zinc (two component material with polyamid hardener) as primary with a pneumatic gun. Thickness of primary is between 40µm and 70µm
- External surfaces are painted by "ISO 12944-5/S5.06-EP/PUR" system. Layer thickness between 200µm and 240µm

Primary is achieved by epoxy rich in zinc (>90% in weight), in two components and hardener. Thickness of this layer is between 100µm and 120µm.

Final layer is painted Acrylic-Polyurethane and hardener. Thickness between 100µm

Cover,conservator, cable boxes and other tank parts have similar paint process than the distribution transformers.

Tests

Typical test values and performances are performed in the painting lab (Fig 13) on steel plates during the whole painting process in order to confirm the following:

- Minimum paint thickness film (ISO 2808): 70µm
- Specular gloss factor at 60 Deg (ISO 2813): 90 +/- 5%
- Falling weight test (ISO 6272): 1Kg/050cm (Fig 10)
- Erichsen cupping test (ISO 1520): 08mm (Fig 11)
- Scratch test (Adhesion ISO 2409): 0 (Fig 11)
- Bend Test (cylindrical mandrel ISO 1519): 3,0mm

Fig 7 - Surface treatment

Fig 8 - Electrostatic powder paint

Fig 9 - Painting oven

Fig 10 - Falling weight test

Fig 11 - Cupping and scratch tests

Fig 12 - Salt spray test

Fig 13 - Painting lab

Fig 14
LV bushing
(porcelain)

Fig 15
HV bushing
(porcelain)

Fig 16
HV bushing
(plug in)

Fig 17
LV terminals
(bus bars)

Fig 18
LV bushing
(monobloc)

Fig 19
HV bushing
(porcelain BS)

2.4. Accessories for Distribution Transformers

2.4.1. Bushings

The transformer bushings are devices serving to connect the network cables to the primary and secondary windings, through the metallic cover while electrically isolating them. Bushings are chosen depending on the voltage, current and applications.

Table 2: Bushings types & dimensions

Bushing Item No	Type	Name	Standard	Max Voltage kV	Rated Current A	Creepage Distance mm	-A- mm	-B- mm	-C- mm	-D- mm	-E- mm	-F- mm	-G- mm	-H- mm	-J- mm
1	Bus Bar	1/1250	-	1	1250	78	63	12	19	25	35	90	55	11	-
2	Bus Bar	1/1600	-	1	1600	78	63	12	19	25	35	190	55	11	65
3	Bus Bar	1/2500	-	1	2500	57	100	12	37.5	25	35	190	55	11	65
4	Bus Bar	1/1250	-	1	1250	78	63	12	15.75	31.5	31.5	110	57	14.5	-
5	Bus Bar	1/1600	-	1	1600	78	63	12	15.75	31.5	31.5	173	57	14.5	63
6	Bus Bar	1/2500	-	1	2500	57	100	12	15.75	31.5	31.5	185	55	14.5	75
7	Bus Bar	1/3150	-	1	3150	72	120	12	30	60	-	197	58	18	-
8	Bus Bar	1/5000	-	1	5000	70	120	20	30	60	-	258	58	18	-
9	Monobloc	2500 12h	BS 2562	1	2500		63	20	19	25	35	339	75	80	114
10	Monobloc	2500 8h	BS 2562	1	2500		63	20	19	25	35	236	75	80	114
11	Monobloc	1400 8h	BS 2562	1	1400		63	12.5	19	25	35	236	75	80	114
12	Porcelain	1/250	DIN 42530	1	250	55	-	-	-	-	-	138	50	-	12
13	Porcelain	1/630	DIN 42530	1	630	70	-	-	-	-	-	178	65	-	20
14	Porcelain	1/1000	DIN 42530	1	1000	75	80	12	24	32	-	274	194	14	30
15	Porcelain	1/2000	DIN 42530	1	2000	75	100	20	25	50	-	325	225	14	42
16	Porcelain	1/3150	DIN 42530	1	3150	75	120	20	30	60	-	355	235	14	48
17	Porcelain	3/250	DIN 42539	3	250	120	-	-	-	-	-	180	50	-	12
18	Porcelain	3/630	DIN 42539	3	630	120	-	-	-	-	-	210	65	-	20
19	Porcelain	3/1000	DIN 42539	3	1000	125	60	10	17	26	-	290	230	14	30
20	Porcelain	10NF250	DIN 42531	10	250	295	-	-	-	-	85	310	76	150	12
21	Porcelain	20NF250	DIN 42531	20	250	445	-	-	-	-	155	385	76	150	12
22	Porcelain	30NF250	DIN 42531	30	250	600	-	-	-	-	220	485	76	170	12
23	Porcelain	33/250	-	36	250	1320	-	-	-	-	-	576	76	-	12
24	Porcelain	36/250	BS 2562	36	250		-	-	-	-	-	267	25	-	12
25	Porcelain	11/250	BS 2562	12	250		-	-	-	-	-	165	25	-	12
26	Porcelain	17.5/250	-	17.5	250	270	-	-	-	-	-	275	65	-	12
27	Plug in	24-250	EN 50180	24	250	-	-	-	-	-	-	87	-	-	10
28	Plug in	36-400	EN 50180	36	400	-	-	-	-	-	-	132	-	-	16
29	Porcelain	1/250	EN 50386	1	250	55	-	-	-	-	-	133	58	-	12
30	Porcelain	1/630	EN 50386	1	630	70	-	-	-	-	-	165	70	-	20
31	Porcelain	1/1250	EN 50386	1	1250	75	60	10	30	-	-	263	203	14	30
32	Porcelain	1/2000	EN 50386	1	2000	75	100	15	50	-	-	340	240	14	42
33	Porcelain	1/3150	EN 50386	1	3150	75	120	15	60	-	-	375	252	14	48
34	Porcelain	24-250/P2	EN 50180	30	250	490	-	-	-	-	-	384	80	-	12
35	Porcelain	24-250/P3	EN 50180	30	250	605	-	-	-	-	-	437	80	-	12
36	Porcelain	24-250/P3	EN 50180	30	250	605	-	-	-	-	-	437	80	-	12

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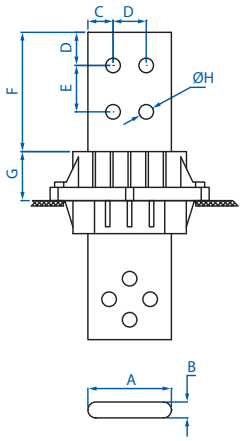

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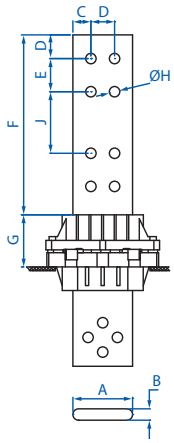

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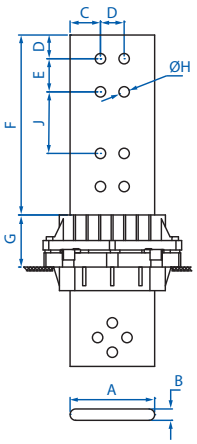

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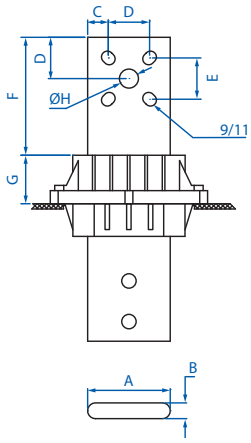

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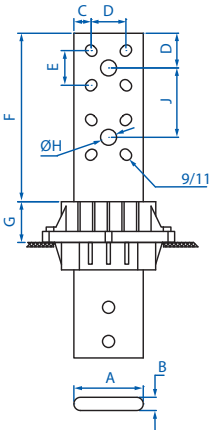

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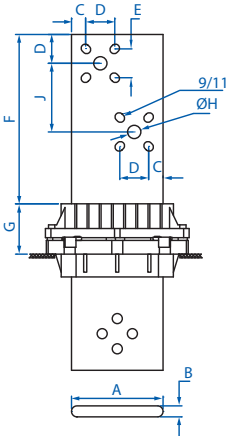

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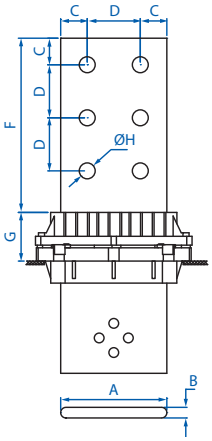

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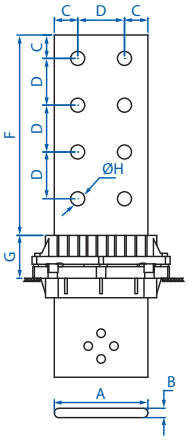

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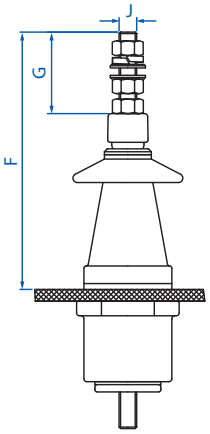

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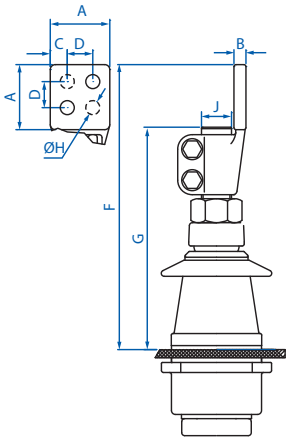

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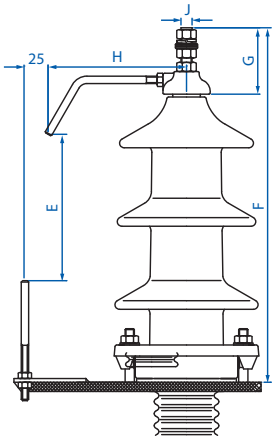

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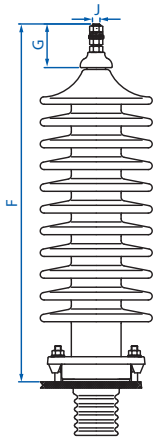

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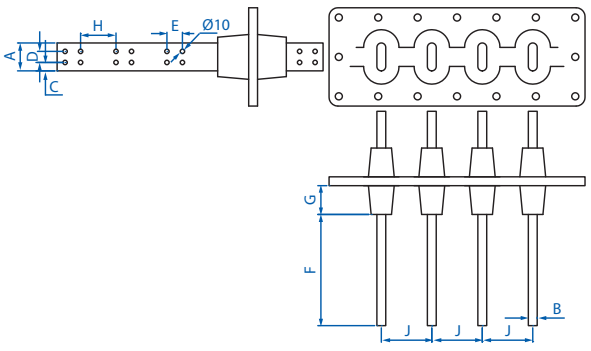

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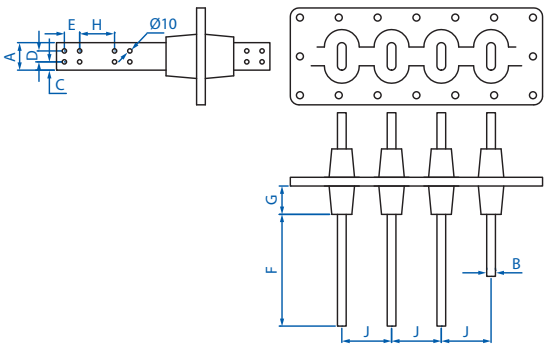

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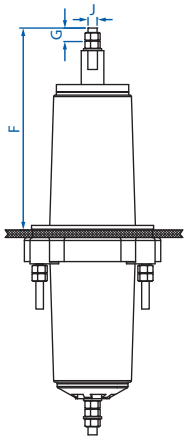

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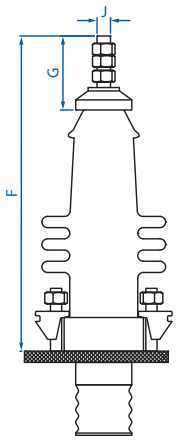

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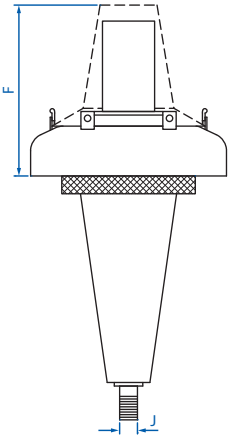
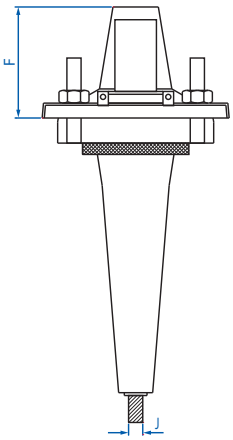
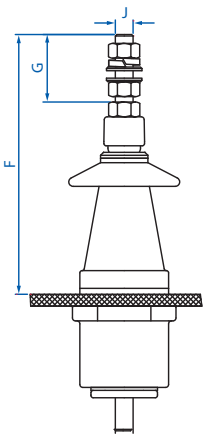


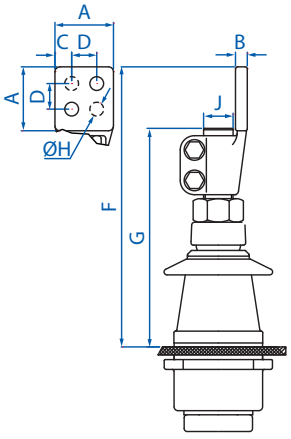
Item 28



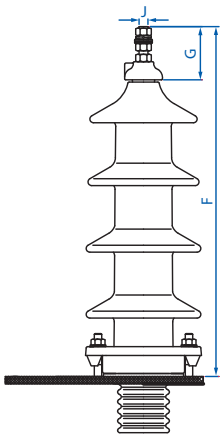
Items 29, 30



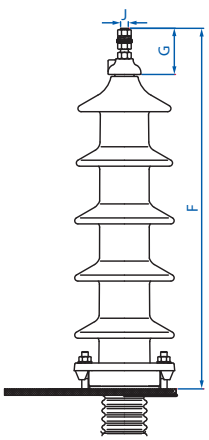
Items 31, 32, 33



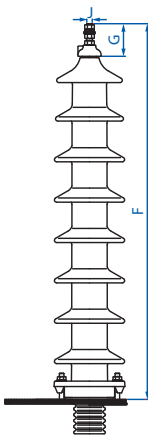
Items 34



Items 35



Items 36



Please unfold to see full drawings page

Fig 20
Cable box MVCB23

Fig 21
Cable box LVCB7 & 8

Fig 22
Cable box LVCB1 to 6

Fig 23 - Cable box LVCB9 to 19 & MVCB 24 to 28

2.4.2. Cable boxes

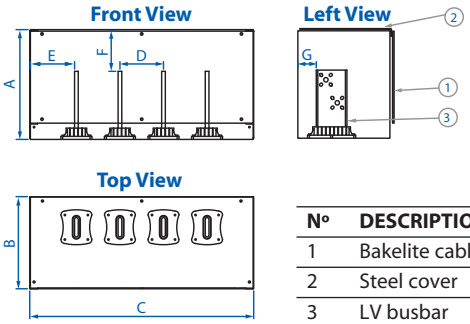
Cable boxes are enclosures for transformers terminals. They protect from hazardous access to terminals, and protect these terminals from water, dust and mechanical impacts up to different degrees. Protection degrees are described in IEC 60529.

Table 3: Air insulated cable boxes and bus ducts

Cable Box Item No	Bushing Type	Bushing Item No (Table 1)	Height -A- mm	Depth -B- mm	Width -C- mm	Between Axis -D- mm	-E- mm	-F- mm	-G- mm	Distance to Cable Entry -H- mm	-J- mm	Insulation Level kV
LVCB1	Busbar 1/1250	Item 4	310	285	670	142	110	135	41	-	-	1
LVCB2	Busbar 1/1600	Item 5	310	285	670	142	110	70	41	-	-	1
LVCB3	Busbar 1/1250	Item 4	350	310	730	142	144	175	99	-	-	1
LVCB4	Busbar 1/1600	Item 5	350	310	730	142	144	110	99	-	-	1
LVCB5	Busbar 1/2500	Item 6	350	310	730	142	144	102	58	-	-	1
LVCB6	Busbar 1/3150	Item 7	580	510	840	180	142	227	98	-	-	1
LVCB7	Porcelain 1/1000	Item 14	410	340	700	150	95	145	58	-	-	1
LVCB8	Porcelain 1/2000	Item 15	410	340	700	160	68	73	40	-	-	1
LVCB9	Monobloc - 8 incoming cables	Item 11	780	370	600	114	120	-	-	600	-	1
LVCB10	Monobloc - 12 incoming cables	Item 9	780	475 *	600	114	120	-	-	600	-	1
LVCB11	Monobloc - 8 incoming cables	Item 10,11	590	375 *	600	114	120	180	70	410	-	1
LVCB12	Porcelain 1/250	Item 12	530	235	550	110	84	380	90	-	-	1
LVCB13	Porcelain 1/630	Item 13	530	235	550	110	76	380	50	-	-	1
LVCB14	Porcelain 3/250	Item 17	660	270	620	140	84	380	90	-	-	3
LVCB15	Porcelain 3/630	Item 18	660	270	620	140	76	380	60	-	-	3
LVCB16	Porcelain 3/1000	Item 19	770	370	620	140	70	480	80	-	-	3
LVCB17	Busbar 1/1250	Item 1	670	180	810	180	85	85	90	520	-	1
LVCB18	Busbar 1/2500	Item 3	670	280	810	180	65	85	90	500	-	1
LVCB19	Busbar 1/3150	Item 7	670	295	810	180	65	85	90	485	-	1
LVBD20	Busbar 1/1250	Item 1	315	**	630	142	530	117	120	**	62	1
LVBD21	Busbar 1/2500	Item 3	315	**	630	142	530	117	20	**	44	1
LVBD22	Busbar 1/5000	Item 8	415	**	775	180	530	117	50	**	44	1
MVCB23	Porcelain 10/250A	Item 20	430	390	770	240	145	89	-	-	-	12
MVCB24	Porcelain 12/250A	Item 25	780	230	410	105	93	58	-	560	-	12
MVCB25	Porcelain 12/250A	Item 25	735	250	470	105	123	78	150	525	-	12
MVCB26	Porcelain 17.5/250A	Item 26	730	420	790	230	210	110	130	550	-	17.5
MVCB27	Porcelain 10NF250A	Item 20	730	420	790	230	210	110	95	550	-	12
MVCB28	Porcelain 36/250A	Item 24	930	720	1000	250	200	178	165	650	-	36

* *For every 4 additional incoming cables, the depth increases by 115mm*
** *Fixed upon order*
Other bushings can be provided upon request

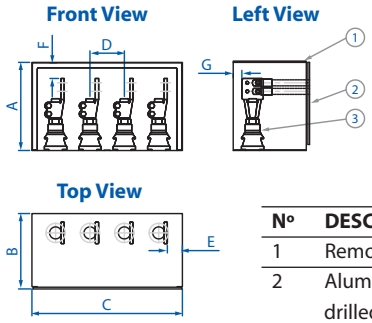
Item LVCB 1 to LVCB 6: LV air insulated cable box bus bars, cover mounted, side or top entry according to NF



N°	DESCRIPTION
1	Bakelite cable entry
2	Steel cover
3	LV busbar

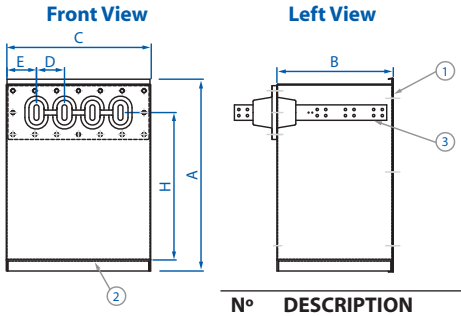
* The steel cover and the bakelite cable entry are interchangeable to provide top cable entry

Item LVCB 7 & LVCB 8: LV air insulated cable box porcelain bushings, cover mounted aluminium side entry



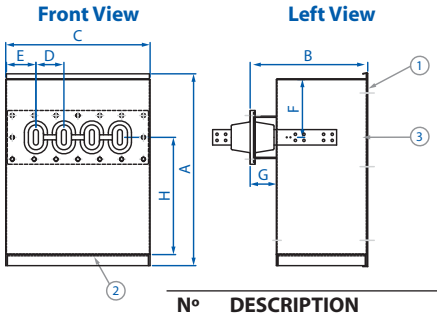
N°	DESCRIPTION
1	Removable steel cover
2	Aluminium cable entry, drilled upon request
3	LV bushing

Item LVCB 9 & LVCB 10: LV air insulated cable box monobloc terminal, side mounted aluminium bottom entry



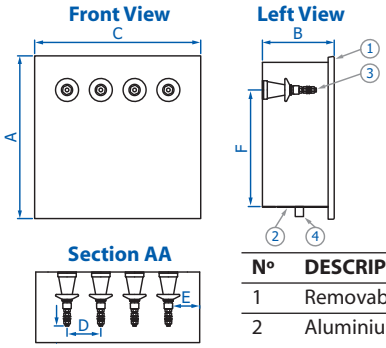
N°	DESCRIPTION
1	Removable steel cover
2	Aluminium cable entry, drilled upon request
3	LV monobloc terminal

Item LVCB 11: LV air insulated cable box monobloc terminal, side mounted aluminium bottom entry



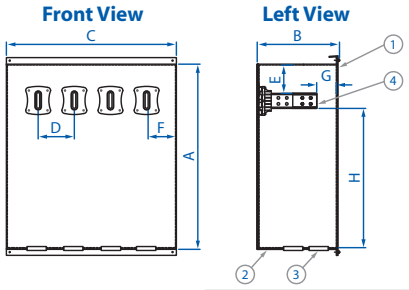
N°	DESCRIPTION
1	Removable steel cover
2	Aluminium cable entry
3	LV monobloc terminal

Item LVCB 12 to LVCB 16: LV air insulated cable box porcelain bushings, side mounted aluminium bottom entry



N°	DESCRIPTION
1	Removable steel cover
2	Aluminium bottom cable entry
3	LV porcelain bushing
4	LV cable glands (optional)

Item LVCB 17 to LVCB 19: LV air insulated cable box bus bars, side mounted aluminium bottom entry

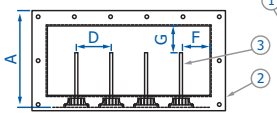


N°	DESCRIPTION
1	Removable steel cover
2	Aluminium cable entry
3	Rubber gaskets for LV cables*
4	LV bus bars

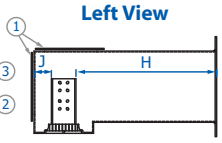
* Number should be fixed on order

Item LVBD 20 to LVBD 22: LV air insulated bus duct bus bars , cover mounted duct side entry

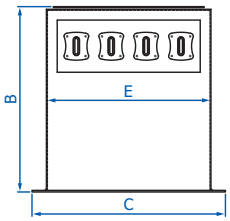
Front View



Left View



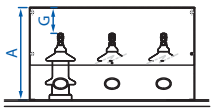
Top View



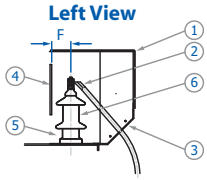
Nº	DESCRIPTION
1	Removable steel covers
2	Flange
3	LV bus bars

Item MVCB 23: MV air insulated cable box porcelain bushings, cover mounted entry at 45º

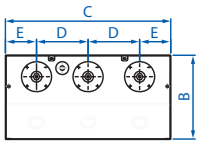
Front View



Left View



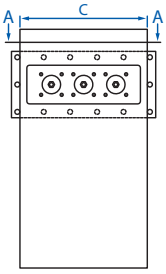
Top View



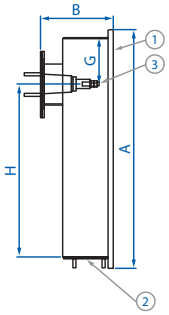
Nº	DESCRIPTION
1	Removable steel cover
2	Tubular angle cable lugs standard type 45º (not supplied)
3	Aluminium cable entry at 45º with 3 rubber gaskets: maximum cable diameter 45mm
4	Repoglass screen
5	Tap changer inside cable box
6	MV porcelain bushing

Item MVCB 24 & MVCB 25: MV air insulated cable box porcelain 11kV bushings, side mounted bottom entry

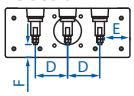
Front View



Left View



Section AA

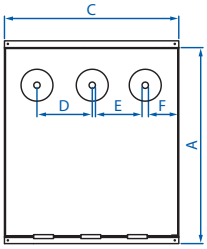


Nº	DESCRIPTION
1	Removable steel cover
2	Aluminium bottom cable entry*
3	MV bushing 11kV, BS2562

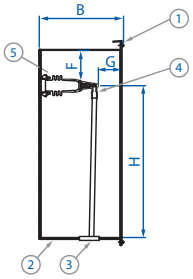
*Drilled as standard for one gland Y, BS2562. Other drilling upon request.

Item MVCB 26 & MVCB 27: MV air insulated cable box porcelain bushings, side mounted aluminium bottom entry

Front View



Left View

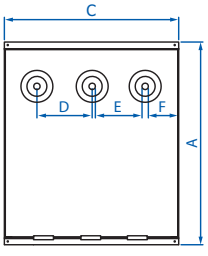


Nº	DESCRIPTION
1	Removable steel cover
2	Aluminium cable entry
3	Rubber gaskets for MV cables*
4	Right angle shrinkable boots**
5	MV bushing porcelain 17.5kV

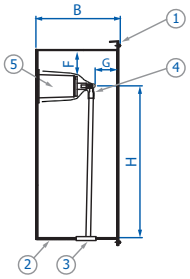
*Number should be fixed on order
** Nor obligatory, just for extra safety

Item MVCB 28: MV air insulated cable box porcelain 36kV bushings BS2562, side mounted bottom entry

Front View



Left View



Nº	DESCRIPTION
1	Removable steel cover
2	Cable entry
3	Rubber gaskets for MV cables*
4	Right angle shrinkable boots (OBLIGATORY)
5	MV bushing porcelain 36kV BS2562

*Replaceable by gland

Please unfold to see full drawings page

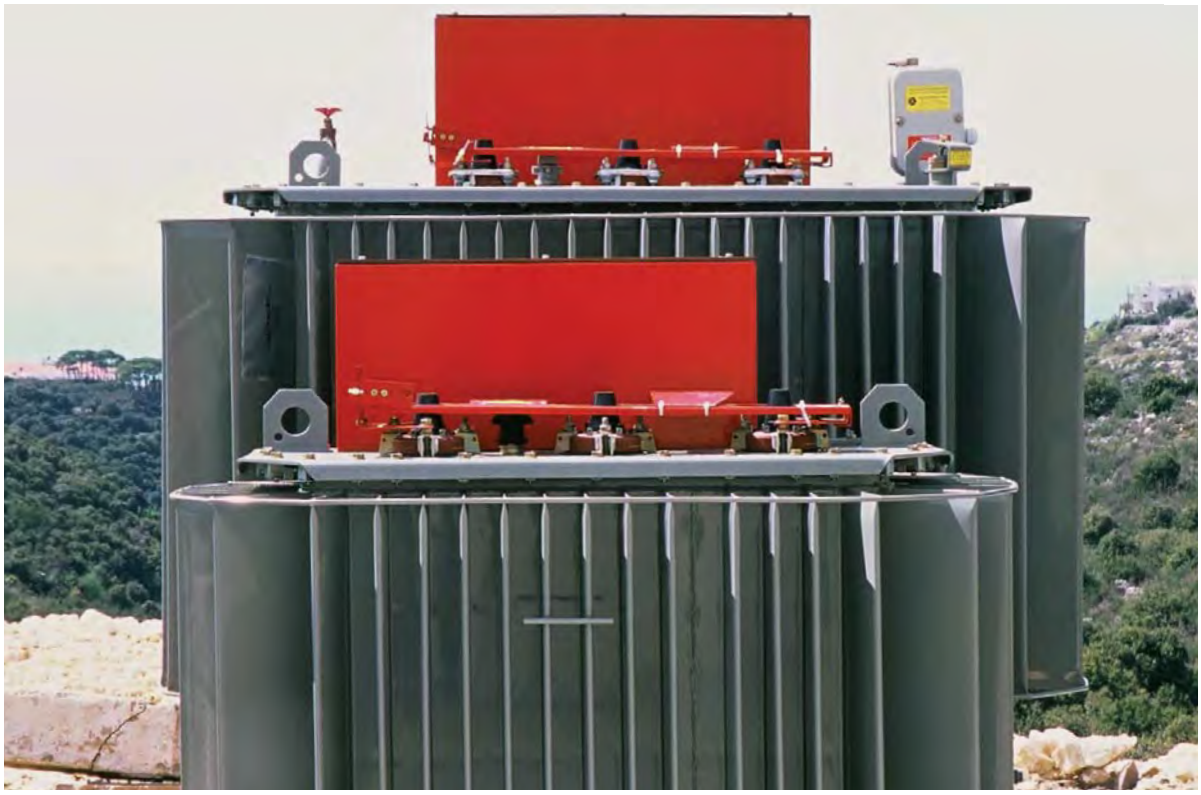


Fig 24
Lifting lug

Fig 25
Roller

Fig 26
Tap changer

Fig 27 & 28
Transformer thermometer

Fig 29
Transformer with conservator

Fig 30
Buchholz relay

2.4.3. Other accessories

These accessories are suitable for transformers ratings less than 2500kVA. For higher ratings, other specific catalogues are provided separately.

- **Lifting lugs** (Fig 24)
  Lifting lugs are used for untanking and lifting. 2 lugs are supplied for units weighing up to 3.5 tons, 4 lugs for heavier units.
- **Rollers** (Fig 25, Table 4)
  Bi-directional rollers are used for ground mounted units: ∮125mm for ratings up to 1600kVA and ∮160mm for higher ratings.

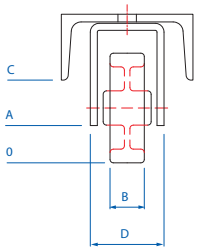


Table 4: Rollers dimensions

Power kVA	Rollers Center to Center mm	Rollers Diameter mm	-A- mm	-B- mm	-C- mm	-D- mm
25-200	520	125	42	40	100	90
250-800	670	125	42	40	95	90
1000-1600	820	125	42	40	90	90
2000-2500	820	160	55	50	107	95

- **Voltage selector**
  The voltage selector is used on dual primary transformers to select the required primary voltage.
- **Tap changer** (Fig 26)
  The network voltage is usually not stable and varies between different locations. To keep the secondary voltage at nominal value, a linear tap changer is used. The default tapping values are ±2.5 and ±5%, other values and more taps can be applied. The different taps are indicated on the rating plate.
  The tap changer is off-circuit operated. On-load tap changer with automated regulation can be implemented.
- **Transformer thermometer** (Fig 27 & 28)
  The dial type thermometer with maximum indicator indicates the top oil temperature. The maximum indicator pointer indicates the highest temperature reached during a certain period.
  Two contacts are optional to provide an electrical signal. Usually, the first is for alarm and the second for tripping.
- **Oil conservator** (Fig 29)
  During operation, the cooling medium is heated and expands into the conservator.
- **Buchholz relay** (Fig 30)
  The Buchholz relay is used in conjunction with the conservator. Oil leakages, gases formation, and quick oil flow to the conservator are internal faults detected by the Buchholz relay. Dry contacts are provided to signal these alarms.

Fig 31
DGPT2 relay

Fig 32
Air breather

Fig 33, 34 & 35 – Filling and draining means

Fig 36, 37, 38 & 39
Oil level indicators

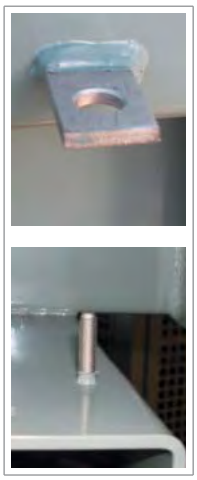


Fig 40 & 41
Earthling

Fig 42
Pressure relief valve

- **DGPT2 relay** (Fig 31)
  A DMCR is a multifunction device. It indicates the temperature and oil level. It is also equipped with electrical contacts for:
  • Gas formation
  • Pressure excess
  • 2 Temperature levels: alarm and trip
- **Air breather** (Fig 32)
  The air breather is installed on the oil conservator.
  During normal operation, the oil temperature changes which results in oil volume change, generating a bi-directional air flow from and to the conservator. The air breather contains silica gel, which absorbs the air moisture.
  On delivery, the silica gel is pink, and becomes colorless when moisturized. Silica gel can be recycled by heating to 120 degrees until the color is back to pink.
- **Filling and draining means** (Fig 33, 34 & 35)
  For filling, the transformers are equipped with a valve or a plug.
  For draining, the transformers are equipped with a valve or, a sampling and draining device.
- **Oil level indicator** (Fig 36, 37, 38 & 39)
  Transformers can be equipped with oil level indicator on the conservator, on the cover or on the side, depending on the design. Magnetic and prismatic types are available.
- **Earthling** (Fig 40 & 41)
  One earthling point is integrated in each lifting lug. Additional points can be provided on the tank and the cover of the transformer. Stainless stud, stainless flag with ∅12mm hole and stainless threaded M10 terminal are the available earthling point types.
- **Pressure relief valve** (Fig 42)
  Hermetically sealed transformers can be equipped with a pressure relief device, preset to 0.3bar which means that when a pressure exceeding 0.3bar occurs inside the transformer, the pressure relief valve opens to evacuate the overpressure.
- **Other accessories**
  Upon request, other accessories can be provided such as:
  • Oil level indicator with contact
  • Pressure relief valve with contact
  • Pressure & vacuum gauge

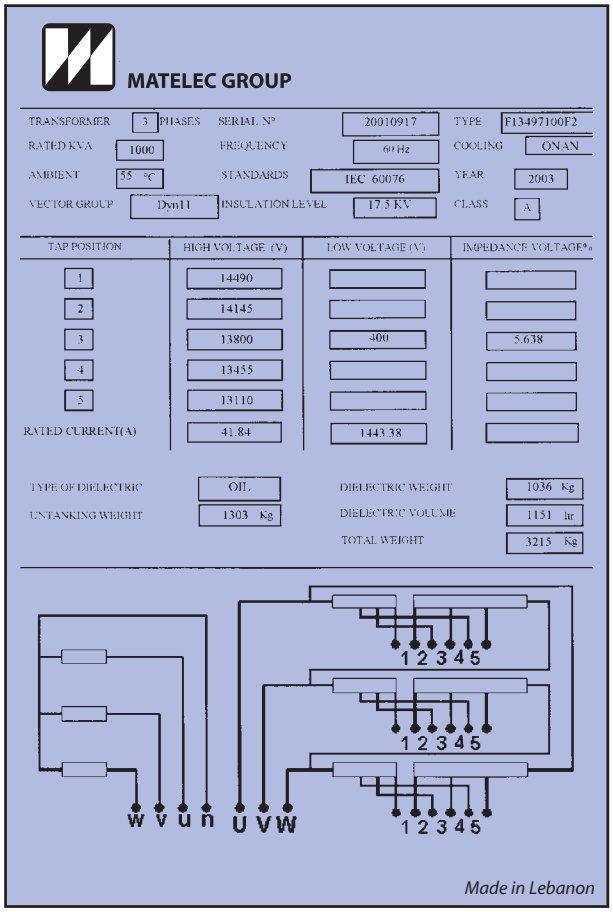


Fig 43 – Rating plate

- **Rating plate** (Fig 43)
  Every transformer is labeled with a name plate. The most common data required by international standards are:

General data:
- Power in kVA
- Serial number
- Year of manufacturing
- Type of transformer
- Number of phases

Electrical data:
- Primary voltage
- Tappings values
- Primary rated current
- Secondary voltage
- Secondary rated current
- Frequency
- Short-circuit impedance (measured value)
- Vector group
- Windings material

Physical and mechanical data:
- Type of cooling
- Maximum ambient temperature
- Winding temperature rise
- Oil temperature rise
- Untanking weight
- Oil weight and volume
- Total weight

2.5. Accessories for Power Transformers

2.5.1. Basic accessories

- Regulating off-circuit tap changer
- Porcelain bushings on primary and secondary sides
- Buchholz relay with 2 contacts (alarm and tripping)
- 2 x lifting and untanking lugs
- 4 x bidirectional rollers
- Rating plate
- Thermometer with maxima indicator
- Oil level indicator on the conservator
- Pressure relief device
- Oil draining and sampling valve
- Oil filling valve
- 2 x earthling terminals
- Inspection openings

2.5.2. Optionnal accessories

Each distribution transformer can be equipped with:

- Regulating on-load tap changer with:
  - Motor drive
  - Conservator compartment with oil level indicator
  - Voltage regulating relay
- Conservator oil level indicator with contacts
- Oil thermometer with 2 contacts (alarm and tripping)
- Pressure relief device with 2 contacts (alarm and tripping)
- Plug In bushings for primary and/or secondary sides
- Cable box or disconnecting chamber for primary and/or secondary sides
- Condenser bushings
- High creepage distance porcelain bushings
- Plug In bushings for primary and/or secondary sides
- Winding temperature indicator with 2 contacts (alarm and tripping) by thermal image
- Plug in bushings for primary and/or secondary sides
- Current transformers mounted inside tank or around bushing
- Voltage transformer for voltage sensing
- Isolation valves for radiators
- Isolation valve between tank and conservator
- 4 x jacking lugs
- Cooling fans for forced cooled transformers
- Oil recirculation pumps oil directed or oil forced transformers
- Electronic control and protection unit
- Rubber bag for conservator

Due to the high number of accessories, options and characteristics, please consult us for more details.

3- TESTING, OPERATION, INSTALLATION AND MAINTENANCE

3.1. Transformer Tests

The IEC 60076 classifies the transformer tests as follows:

- Routine tests,
- Type tests,
- Special tests.

Matelec has the following test platforms:

- Two for distribution transformers (routine, type and special tests)
- One for power transformers (routine, type and special tests)
- One dedicated acoustic room for sound level measurement.

Matelec laboratories are equipped with up-to-date facilities and instruments to perform the complete set of tests except the short circuit test.

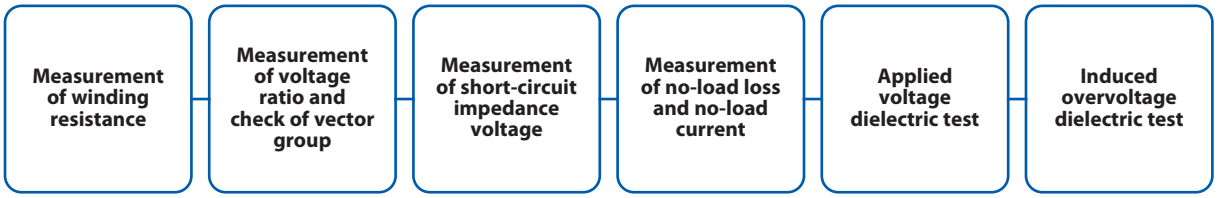


Figure 44 – Routine test procedure

3.1.1. Routine Tests

Routine tests for all transformers:

- Measurement of winding resistance (IEC 60076-1; § 11.2),
- Measurement of voltage ratio and check of phase displacement (IEC 60076-1; § 11.3),
- Measurement of short-circuit impedance and load loss (IEC 60076-1; § 11.4),
- Measurement of no-load loss and current (IEC 60076-1; § 11.5),
- Dielectric routine tests (IEC 60076-3; § 11 12),
- Tests on on-load tap-changers (IEC 60076-1; § 11.7),
- Check of core and frame insulation for liquid immersed transformers with core or frame insulation (IEC 60076-1; § 11.12)

Additional routine tests for transformers with Um > 72,5 kV:

- Determination of capacitances windings-to-earth and between windings,
- Measurement of d.c. insulation resistance between each winding to earth and between windings,
- Measurement of dissipation factor (tan) of the insulation system capacitances,
- Measurement of dissolved gasses in dielectric liquid from each separate oil, compartment except diverter switch compartment,
- Measurement of no-load loss and current at 90 % and 110 % of rated voltage (IEC 60076-1; § 11.5).

Figure 47 - Calibration lab

Figure 48 - Paint aging test (salt spray)

3.1.2. Type tests

- Temperature rise type test (IEC 60076-2)
- Dielectric type tests (IEC 60076-3).
- Determination of sound level (IEC 60076-10) for each method of cooling for which a guaranteed sound level is specified.
- Measurement of the power taken by the fan and liquid pump motors.
- Measurement of no-load loss and current at 90% and 110% of rated voltage.

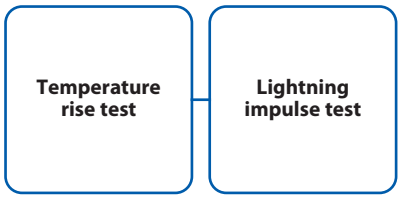


Figure 45 – Type tests procedure

3.1.3. Special tests

- Measurement of D.C. insulation resistance each winding to earth and between windings,
- Determination of capacitances windings-to-earth, and between windings
- Measurement of dissipation factor (tan delta) of the insulation system capacitances (IEEE 62-1995, IEEE C57.19.01)
- Measurement of frequency response (Frequency Response Analysis or FRA), (IEC 60076-18)
- Measurement of zero-sequence impedance(s) on three-phase transformers (IEC 60076 - § 11.6)
- Dielectric special tests (IEC 60076-3)
- Winding hot-spot temperature-rise measurements (see temperature-rise type test)
- Determination of transient voltage transfer characteristics (Annex B of IEC 60076-3)
- Short-circuit withstand test (IEC 60076-5), usually performed either in KEMA – The Netherlands or in CESI - Italy
- Measurement of dissolved gasses in dielectric liquid

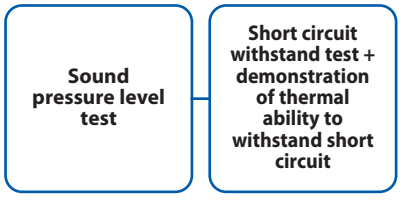


Figure 46 – Special tests procedure

Matelec owns several certificates of type and special tests delivered by renowned laboratories such as KEMA Laboratories in the Netherlands, CESI in Italy and EDF Laboratories in France (Fig 50, Table 5).

KEMA

18-08

TYPE TEST CERTIFICATE OF SHORT-CIRCUIT PERFORMANCE

APPARATUS	A three-phase oil-immersed distribution transformer
DESIGNATION	FF046602 **SERIAL No.** 20062422
Rated power	630 kVA
Rated voltage	20 kV ± 2,5% / 410 V
Connection symbol	Dyn11
Rated frequency	50 Hz
MANUFACTURER	MATELEC sal, Ghorfine, Amchit, Lebanon
TESTED FOR	MATELEC sal, Ghorfine, Amchit, Lebanon
TESTED BY	KEMA HIGH-POWER LABORATORY Utrechtseweg 310 - 6812 AR Arnhem - The Netherlands
DATE(S) OF TESTS	20 February and 7, 10, 11 March 2008

The apparatus, constructed in accordance with the description, drawings and photographs incorporated in this Certificate, has been subjected to the series of proving tests in accordance with

IEC 60076-5

This Type Test Certificate has been issued by KEMA following exclusively the STL Guides.

The results are shown in the record of Proving Tests and the oscillograms attached hereto. The values obtained and the general performance are considered to comply with the above Standard with respect to the dynamic ability to withstand short-circuits.

This Certificate applies only to the apparatus tested. The responsibility for conformity of any apparatus having the same designations with that tested rests with the Manufacturer.

This Certificate consists of 35 sheets in total.

Certificate falls under the scope of the accreditation certificates L 020 and L 218 of the Dutch Council for Accreditation formation sheet (page 2).

KEMA Nederland B.V.

P.E.A. Bus
KEMA T&D Testing Services
Managing Director

Arnhem, 21 April 2008

Figure 50 – Short circuit test certificate

Table 5: Independent laboratories certificates

Laboratory Name	Certificate Number	Description	Manufacturer	Tests Performed	Standards
LCIE-France	83747-574302	160kVA 20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)		HN52-S-27
EDF-France	HM 21/20-842			Routine tests	IEC 60076-1
	83594-573899	250kVA 20/0.41kV ONAN Dyn11 50Hz		Lightning impulse test	IEC 60076-3
	HM 21/20-843			Temperature rise test	IEC 60076-2
	83598-573908	400kVA 20/0.41kV ONAN Dyn11 50Hz		Short circuit test	IEC 60076-5
	HM 21/20-844			Noise level test	IEC 60076-10
	83596-573906	630kVA 20/0.41kV ONAN Dyn11 50Hz		Partial discharge test	Client specs
	HM 21/20-845				
	83595-573903	1000kVA 20/0.41kV ONAN Dyn11 50Hz			
	HM 21/20-846				
CESI	A8027459	5000kVA 11/3.45kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
LCIE-France	396272	400kVA 20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Dielectric routine test	NF C52/HN 52
				Dielectric type test	NF C52/HN 52
				Partial discharge test	NF C52/HN 52
LCIE-France	371486	1000kVA 20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Routine tests	NF C52
				Temperature rise test	NF C52
LCIE-France	329521 A	630kVA 20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Routine tests	UTE C52
				Partial discharge test	UTE C53
				Temperature rise test	UTE C54
EDF-France	HM-51/20.86/1	1000kVA 20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
	HM-51/20.86/2			Noise level test	IEC 60076-10
EDF-France	HM-51 20956/1	630kVA 20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
	HM-51 20956/2			Noise level test	IEC 60076-10
EDF-France	HM-51 20406	500kVA 15/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
Pyramids	65/98	1500kVA 11/0.4kV ONAN Dyn11 50Hz	International	Oil breakdown voltage test	IEC 60156
High Voltage	66/98	500kVA 11/0.4kV ONAN Dyn11 50Hz	Transformers	Routine tests	IEC 60076
Research	67/98	500kVA 22/0.4kV ONAN Dyn11 50Hz	Matelec	Temperature rise test	IEC 60076-2
Center	68/98	1000kVA 11/0.4kV ONAN Dyn11 50Hz	(Egypt)		
Egypt	69/98	1000kVA 22/0.4kV ONAN Dyn11 50Hz			
KEMA	90-99	500kVA 22/0.4kV ONAN Dyn11 50Hz	International	Routine tests	IEC 60076-1
	91-99	1000kVA 22/0.4kV ONAN Dyn11 50Hz	Transformers	Lightning impulse test	IEC 60076-3
			Matelec	Temperature rise test	IEC 60076-2
			(Egypt)	Short circuit test	IEC 60076-5
				Partial discharge test	Client specs
KEMA	92-99	1000kVA 13.8/0.4kV ONAN Dyn11 60Hz	Matelec (Lebanon)	Routine tests	IEC 60076-1
				Lightning impulse test	IEC 60076-3
				Temperature rise test	IEC 60076-2
				Sound level test	IEC 60551
				Short circuit test	IEC 60076-5
KEMA	1260-99	500kVA 22/0.4kV ONAN Dyn11 50Hz	International	Sound level test	IEC 60551
			Transformers		
			Matelec		
			(Egypt)		
KEMA	105-00	300kVA 11/0.4kV ONAN Dyn11 50Hz	International	Short circuit test	IEC 60076-5
			Transformers		
			Matelec		
			(Egypt)		
KEMA	1121-00	300kVA 11/0.4kV ONAN Dyn11 50Hz	International	Routine tests	IEC 60076-1
			Transformers	Lightning impulse test	IEC 60076-3
			Matelec	Temperature rise test	IEC 60076-2
			(Egypt)	Sound level test	IEC 60551
				Partial discharge test	Client specs
KEMA	16993A-01	1000kVA 11-20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Inspection on lightning Impulse test in Matelec laboratories	IEC 60076-3
KEMA	16984A-01	250kVA 11-20/0.41kV ONAN Dyn11 50Hz Idem 400kVA,630kVA,1000kVA 160kVA 15-20/0.41kV ONAN Yzn11 50Hz Idem 250kVA,400kVA,630kVA,1000kVA Dyn11	Matelec (Lebanon)	Inspection on routine test in Matelec laboratories	IEC 60076-1 IEC 60076-3
KEMA	51-02	630kVA 30/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
	52-02	400kVA 30/0.4kV ONAN Dyn11 50Hz			
	53-02	160kVA 30/0.4kV ONAN Yzn11 50Hz			
	54-02	100kVA 30/0.4kV ONAN Yzn11 50Hz			
KEMA	110-02	630kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (Jordan)	Short circuit test	IEC 60076-5
	111-02	1000kVA 11/0.415kV LNAN Dyn11 50Hz	(under license		
	112-02	1500kVA 11/0.415kV LNAN Dyn11 50Hz	from Matelec)		

Laboratory Name	Certificate Number	Description	Manufacturer	Tests Performed	Standards
KEMA	113-02	500kVA 13.8/0.4kV ONAN Dyn11 60Hz	Matelec (Lebanon)	Lightning impulse test Temperature rise test IEC 60076-2 Short circuit test	IEC 60076-3 IEC 60076-5
KEMA	3-03	630kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (Jordan) (under license from Matelec)	Short circuit test	IEC 60076-5
KEMA	54-03	1000kVA 22-11/0.433kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Routine tests Lightning impulse test Short-circuit test Noise Level Test	IEC 60076-1 IEC 60076-3 IEC 60076-5 IEC 60076-10
KEMA	10-05	250kVA 30/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	11-05	250kVA 10/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	12-05	300kVA 33/0.231kV ONAN Dyn11 60Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	49-05	400kVA 10/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	50-05	630kVA 10/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	51-05	100kVA 13.8/0.231kV ONAN Dyn11 60Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	79-05	250kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	80-05	1000kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	81-05	1500kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	82-05	160kVA 10/0.4kV ONAN Yzn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	88-05	630kVA 23/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test Sound level test Lighning impulse test	IEC 60076-5 IEC 60076-10 IEC 60076-3
KEMA	89-05	400kVA 9.25/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test Sound level test Lighning impulse test	IEC 60076-5 IEC 60076-10 IEC 60076-3
KEMA	90-05	630kVA 9.25/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test Sound level test Lighning impulse test	IEC 60076-5 IEC 60076-10 IEC 60076-3
KEMA	91-05	400kVA 23/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test Sound level test Lighning impulse test	IEC 60076-5 IEC 60076-10 IEC 60076-3
KEMA	93-05	250kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	94-05	1000kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	95-05	1500kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	96-05	250kVA 30/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	202-06	100kVA 20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	Client specs
KEMA	203-06	160kVA 20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	Client specs
KEMA	204-06/205-06	100kVA 10-20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	Client specs
KEMA	206-06	160kVA 10-20/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	Client specs
KEMA	222-06	160kVA 15/0.4kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	Client specs
KEMA	151-06	2000kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	120-07	100kVA 33/0.415kV ONAN Yzn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	17-08	100kVA 11/0.415kV ONAN Yzn11 50Hz	ELICO (Jordan) (under licence from Matelec)	Short circuit test	IEC 60076-5
KEMA	18-08	630kVA 20/0.41kV ONAN Dyn11 50Hz	Matelec (Lebanon)	Short circuit test	IEC 60076-5
KEMA	5-08	20/25MVA 33/11kV KNAN/KNAF Dyn1 50Hz	Matelec (Lebanon)	Short circuit test Lightning impulse test	IEC 60076-5 IEC 60076-3

Laboratory Name	Certificate Number	Description	Manufacturer	Tests Performed	Standards
KEMA	17-08	100kVA 11/0.415kV ONAN Yzn11 50Hz	ELICO(Jordan)	Short circuit test	IEC 60076-5
KEMA	18-08	630kVA 20/0.415kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
KEMA	268-09	50kVA 15/0.415kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	Client specs
KEMA	269-09	50kVA 20/0.415kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	Client specs
KEMA	194-09	250kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Lightning impulse test	IEC 60076-3
				Harmonics of no-load current	--
				Zero-sequence impedance	IEC 60076-1
				Noise level test	IEC 60076-10
				Temperature rise test	IEC 60076-2
				Short circuit test	IEC 60076-5
KEMA	195-09	400kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Lightning impulse test	IEC 60076-3
				Harmonics of no-load current	--
				Zero-sequence impedance	IEC 60076-1
				Noise level test	IEC 60076-10
				Temperature rise test	IEC 60076-2
				Short circuit test	IEC 60076-5
KEMA	196-09	630kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Lightning impulse test	IEC 60076-3
				Harmonics of no-load current	--
				Zero-sequence impedance	IEC 60076-1
				Noise level test	IEC 60076-10
				Temperature rise test	IEC 60076-2
				Short circuit test	IEC 60076-5
KEMA	197-09	1000kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Lightning impulse test	IEC 60076-3
				Harmonics of no-load current	--
				Zero-sequence impedance	IEC 60076-1
				Noise level test	IEC 60076-10
				Temperature rise test	IEC 60076-2
				Short circuit test	IEC 60076-5
KEMA	199-09	630kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
KEMA	200-09	1000kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
KEMA	2021-09	400kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
KEMA	2132-09	2000kVA 33/0.415kV LNAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
CESI	A8036273	1600kVA 11/0.433kV LNAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
	A8035488			Temperature rise test	IEC60076-2
	A8035973			Lightning impulse test	IEC60076-3
CESI	A9021831	2000kVA 3.3/0.433kV LNAN Dyn11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
CESI	A902737015/20MVA 60/31.5kV ONAN/ONAF YNyn0 50Hz		Matelec(Lebanon)	Short circuit test	IEC 60076-5
CESI	B0020568	40MVA 66/15-20kV ONAN/ONAF YNd11 50Hz	Matelec(Lebanon)	Short circuit test	IEC 60076-5
KEMA	2176-11	400kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	IEC 60076-5
KEMA	2177-11	400kVA 11/0.415kV ONAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	IEC 60076-5
KEMA	TIC 2187	250kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2188	400kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2189	630kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2190	1000kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2007-12	1500kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	IEC 60076-5
KEMA	TIC 2008-12	1000kVA 11/0.415kV LNAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	IEC 60076-5
KEMA	TIC 3052-11	1000kVA 13.8/0.4kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories	IEC 60076-3
				Inspection on routine test in Matelec sal laboratories	IEC 60076-1
				Inspection on temperature rise test in Matelec sal laboratories	IEC 60076-2
				Inspection on sound level test in Matelec sal laboratories	IEC 60076-10
KEMA	TIC 3053-11	200kVA 11-13.8/0.4kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories	IEC 60076-3
				Inspection on routine test in Matelec sal laboratories	IEC 60076-1
				Inspection on temperature rise test in Matelec sal laboratories	IEC 60076-2
				Inspection on sound level test in Matelec sal laboratories	IEC 60076-10
KEMA	TIC 3054-11	1500kVA 33/0.4kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories	IEC 60076-3
				Inspection on routine test in Matelec sal laboratories	IEC 60076-1
				Inspection on temperature rise test in Matelec sal laboratories	IEC 60076-2
				Inspection on sound level test in Matelec sal laboratories	IEC 60076-10

Laboratory Name	Certificate Number	Description	Manufacturer	Tests Performed	Standards
KEMA	TIC 3055-11	1500kVA 13.8/0.4kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3056-11	200kVA 34.5/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3057-11	500kVA 13.8/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3058-11	1000kVA 13.8/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3166-11	300kVA 13.8-11/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3167-11	500kVA 13.8-11/0.4kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3168-11	500kVA 13.8-11/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 3169-11	1000kVA 13.8-11/0.231kV ONAN Dyn11 60Hz	Matelec sal	Inspection on lightning impusle test in Matelec sal laboratories Inspection on routine test in Matelec sal laboratories Inspection on temperature rise test in Matelec sal laboratories Inspection on sound level test in Matelec sal laboratories	IEC 60076-3 IEC 60076-1 IEC 60076-2 IEC 60076-10
KEMA	TIC 2061-12	40000kVA 60/10.5kV ONAF YNd11 50Hz	Matelec sal	Short circuit test Dissolved gas analysis	IEC 60076-5 IEC 60559
KEMA	TIC 2062-12	90000kVA 132/33kV ONAF YNd11 50Hz	Matelec sal	Short circuit test Dissolved gas analysis Inspection in Matelec SAL on: Capacitance and dissipation fact. Leak test Zero-sequence impedance Partial discharge test Noise level Temperature rise test Lightning impusle test Dissolved gas analysis	IEC 60076-5 IEC 60559 IEEE 62-1995 IEC 60076-1 IEC 60076-6 IEC 60270 IEC 60076-10 IEC 60076-2 IEC 60076-3 IEC 60559
KEMA	TIC 2049-12	1000kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2001-13	630kVA 11/0.415kV ONAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	IEC 60076-5
KEMA	TIC 2004-13	400kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test	IEC 60076-5
KEMA	TIC 2005-13	400kVA 11/0.416kV ONAN Dyn11 50Hz	Matelec sal	Short circuit test (9x1sec+1x5sec)	IEC 60076-5
KEMA	TIC 2406-13	400kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	3 seconds SC test
KEMA	TIC 2407-13	400kVA 33/0.415kV ONAN Dyn11 50Hz	ELICO (under licence from Matelec sal)	Short circuit test	3 seconds SC test

3.2. Distribution Transformer Operation

3.2.1. Set up (for distribution transformers)

After installing and before energizing the transformer for the first time, a certain number of checks should be carried:

- Check the transformer for any damage during transportation and installation.
- Check the information on the rating plate for compatibility with the order and the network characteristics.
- Check the oil level.
- Check that all terminals are not subject to undesirable mechanical stresses by connection cables, which could cause leakage or breaking the bushings. The cables should have enough flexibility.
- Check the resistance of the windings at all taps and check the tap changer handle is in a service position.
- Check the set-up of all fittings, and the continuity of their wirings.
- Energize the apparatus and before closing the secondary circuit, measure the off-load voltage.

This should be done by qualified technician and all proper security measures should be taken.

3.2.2. Overloading

It is very unlikely to have a constant load on the transformer. The load is usually cyclic.

Overload limits should be respected. These limits are defined according to the previous status of loading.

The table hereafter is an example of permissible overloading considered for ambient temperature of 30°C. At the end of the overload duration, the temperature of the windings is 120°C without affecting the lifetime of the transformer.

Table 6: Overload table

Overloading After Previous Continuous Loading Status at:			Permissible Overload Duration in Minutes
full load %	3/4 load %	1/2 load %	
15	20	25	120
25	32	40	60
30	40	50	30
40	55	70	15
50	70	90	10
80	100	100	5
100	100	100	2

Depending on the standards to which the transformer was designed, other overloading tables would apply.

3.2.3. Inrush current

During the operation of the transformer, the brutal application of voltage on the primary winding (the secondary being open) produces a unidirectional high current called the inrush current. This current reaches almost instantaneously its peak value then decreases exponentially until it reaches its nominal value, in nearly one second. The peak values of the current -limited to few periods, reach sometimes the amplitude of the short circuit current.
During the inrush period, the transformer behaves like a self-induction coil.
The peak value of the inrush current depends on:

- The characteristics of the magnetic steel core and the windings (cross section of the core, induction, number of turns, geometry of the windings),
- The characteristics of the magnetic steel used in the transformer (residual induction, saturation) and,
- The magnetic state of the magnetic core columns and the value of the alternating voltage at the in-rush instant.

The inrush current can be controlled by limiting the induction or by using, during the start-up period, an impedance causing an important voltage drop. When the system reaches its nominal current, the impedance is short circuited.

3.2.4. Transformer protection

The protection of a transformer is intended to:

- Protect the transformer against exterior perturbation, short-circuit, overvoltage and overload,
- Protect the networks connected to the transformer and,
- Monitor the functioning of the transformer in order to prevent any rising danger and limit the damage in case of accident.

Beside the accessories such as the Buchholz relay, DGPT2 and pressure relief valve, a transformer can be protected by surge arrestors, circuit breaker or fuses.
The surge arrestor with non-linear resistance is intended to be connected between each phase and the earth, in order to protect the transformer against overvoltage due to closing and opening the circuit, and those due to atmospheric reasons.
The circuit breaker limits the current absorbed by the load, thus forbidding any excessive heating of the apparatus. A circuit breaker should be rated according to the nominal current and the required sensitivity.
The fuse limits the overcurrent. It should be rated according to table 7.

Table 7: **Fuse ratings (DIN type)**

Line Voltage (kV)	Transformer rating (kVA)																
	50	75	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500
	High Voltage Fuse-link I_n (A)																
3	25	25	40	40	63	63	63	80	100	100	160	200	200	250	315		
5	16	25	25	25	40	40	63	63	63	80	100	100	160	200	200	250	315
6	16	16	25	25	25	40	40	63	63	63	80	100	100	160	200	200	250
10	10	16	16	16	25	25	25	40	40	63	63	63	80	100	100	160	200
12	10	16	16	16	16	25	25	25	40	40	63	63	63	80	100	160	160
15	10	10	16	16	16	16	25	25	25	40	40	63	63	63	100	100	125
20	10	10	10	16	16	16	16	25	25	25	40	40	63	63	63	80	100
24	10	10	10	10	16	16	16	16	25	25	25	40	40	63	63	63	80
30	10	10	10	10	10	16	16	16	16	25	25	25	40	40	40	2x40	2x40
36	10	10	10	10	10	10	16	16	16	16	25	25	25	40	40	2x40	2x40

Low Voltage (V)	Low Voltage Fuse-link I_n (A)																
220	80	100	125	160	200	250	250	315	400	500	630						
380	50	63	100	100	125	125	200	250	250	350	400	400	500	630			
500	40	50	80	80	100	100	160	160	200	250	350	350	400	500	630		

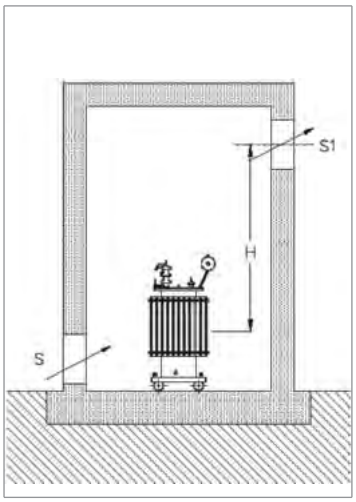


Fig 51 – Ventilation requirements

3.3. Distribution Transformer Installation and Maintenance

3.3.1. Types of transformer installation

- **Pole installation**
  The transformers of ratings up to 250kVA can be mounted on a pole:
  - Using hooks
  - On platform

If this platform is standard or already exists, the dimensions should be submitted with the purchasing order. If the underbase of the transformer cannot be designed to match the platform, an appropriate adapter chassis should be prepared.

- **Ground installation**
  When the rating is higher than 250kVA, the weight of the transformer becomes usually incompatible to be platform mounted. The unit should be ground mounted:
  - Kiosk (package substation)
  The apparatus could be enclosed inside a kiosk placed near the distribution poles.
  - Outdoor
  The apparatus could be installed in an open area, where adequate measures should be taken to forbid any access for persons near the live parts of the unit. The local electrical authorities should be notified for approval.
  - Indoor
  The apparatus could be installed inside a room in a building. The ventilation, protection and access issues should be studied and approved by electrical local authorities. Whether indoor and outdoor, there should be under the transformer an oil collection pit filled with gravel and covered with steel mesh. The capacity of the tank should be bigger than the transformer oil volume and the gravel together. An extraction system for oil from the pit should be provided. Again, any design is subject to the approval of local electrical authorities. The extracted oil should be treated in accordance with the environmental rules and regulations.

3.3.2. Dimensions of transformer installation area

When the transformer has to be installed inside an electrical room, the room should be ventilated. Two openings should be provided on opposite sides of the room, one for air inlet at ground level and the other for air outlet at the ceiling level (Fig 51) .
If we admit an increase in the air temperature of 10°C between the inlet and outlet, the openings surfaces would be calculated as follows:

$$S = \frac{180 \times TL}{10^{\circ} \times \sqrt{H}}$$

$$S_1 = S \times 1.15$$

Where
S is the cross-section area of the inlet opening, in square meters
S_1 is the cross-section area of the outlet opening, in square meters
TL is the value of the total losses of the transformer and other electrical equipment sharing the area, in Watts
H is the difference in level of the outlet opening and the height center line of the transformer, in meters

3.3.3. Maintenance

The transformer requires very little maintenance, especially for the hermetically sealed types.
However, it is a good practice to have periodic preventive maintenances and checks. Before any intervention, the primary and secondary circuits should be turned off, and the transformer should be grounded.

- **Visual inspection (every three months)**
  - Check if the transformer is clean, especially on the surface of insulators (dust and moisture can cause flashover).
  - Check for oil leakage.
  - Check for damage in the transformer painting. In case of scratches or beginning of rust, they should be treated and repainted in order to prevent major rust.
  - Check of the oil level of the oil indicator. If possible when the transformer is cold that is when out of operation for at least 6 hours.
  - Check of the condition of the air dehumidifier silica gel. If the color of the silica gel is pink, then it is in good condition, while if it is colorless, then it must be dried or replaced. Some silicagel have different colors please refer to the label on the air dehumidifier for correct information.
- **Oil check**
  This check can be carried every 3 years for hermetically sealed transformers and every year for other types
  - Check of the oil dielectric strength. This is based on the sample that is taken by opening the draining device. We recommend to perform this check by specialized technicians bearing in mind that any wrong action or equipment can mislead the test.
- **Inspection of equipments (every three years)**
  - Check the operation of the Buchholz relay, thermometer, DMCR, etc., and the condition of their switches by simulating the detectable malfunctions by these accessories. The related instructions of every equipment should be followed.

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