Instruction manual for packaging, transport, handling, storage, installation and maintenance of transformers immersed in insulating liquid for the oil sector

Content

1. Safety and risks

Please read this instruction manual carefully before servicing the product, disregarding the instructions may result in property damage, serious injury, or death.

The product covered in this manual must be operated only by qualified personnel.

This manual contains important information for the safety of personnel and the product.

If any problem not covered in this manual occurs, contact MAGNETRON S.A.S.

When working with transformers, operators are exposed to a series of risks and dangers, it is very important to know them in order to eliminate or minimize situations or conditions that may cause damage.

1.1 Personal security

- Stop any activity if working conditions are unsafe.
- All team members must know the instructions in this manual, the safety practices established in the workplace and the applicable legislation.
- Use clothing and personal protection elements according to the work to be carried out.

  - ✓ Long-sleeved cotton shirt.
  - ✓ Dielectric safety boots.
  - ✓ Bait or dielectric gloves.
  - ✓ Latex gloves (taking samples of the insulating liquid).
  - ✓ Latex gloves (handling tools).
  - ✓ Safety glasses.
  - ✓ Dark glasses for sun protection (field activities).
  - ✓ Helmet.
  - ✓ Avoid wearing loose clothing.
  - ✓ Do not wear rings, watches, chains, earrings or any personal item that could cause harm.
  - ✓ Do not wear tennis shoes, shorts, short-sleeved shirts, and headphones.

1.2 Types of risks

➢ **Physical risks**

It refers to all environmental factors that depend on the physical properties of the bodies and that act on the tissues and organs of the worker's body, can produce harmful effects according to their intensity and exposure time.

They are related to the imminent probability of suffering bodily harm with or without direct contact, they can be classified as labor or environmental.

They are the most common and can be caused by dangerous conditions at work:

- ✓ Noises,
- ✓ Lightning,
- ✓ Temperature,
- ✓ Humidity,
- ✓ Radiations,
- ✓ Vibrations,
- ✓ Electricity.

Listed below are some activities that must be carried out:

- Install localized lighting in those jobs that require it, when general lighting is moderate and may be insufficient.
- Avoid dead flow areas (where air does not circulate).
- Use work equipment that generates low noise levels.
- Locate noisy equipment or sources out of the way, if possible.
- Decrease the exposure time.
- Establish a job site rotation system.
- Use screens or protective shielding, for radioactive sources.
- Apply the 5 golden rules when working with energy.

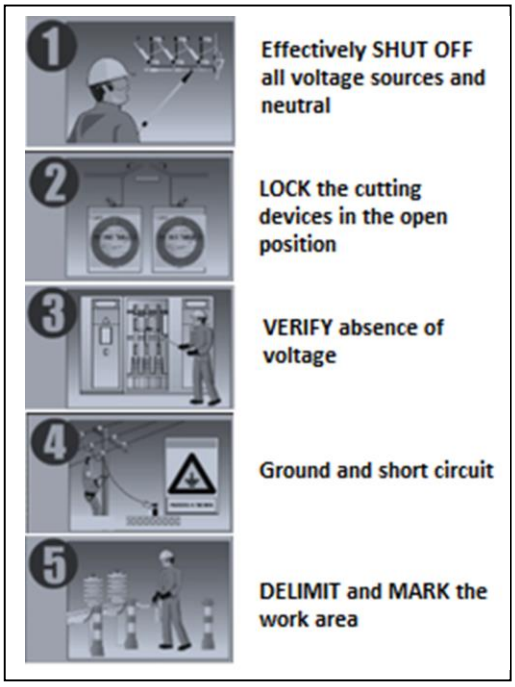


Figure 1: 5 golden rules

➢ Mechanical risks

They are associated with the set of physical factors that can give rise to an injury due to the mechanical action of machine elements, tools, work pieces or projected, solid or fluid materials.

The mechanical risk can occur in any operation that involves manipulation of hand tools, machinery, handling of vehicles, use of lifting devices.

- ✓ Collision with moving or stationary objects,
- ✓ Hits,
- ✓ Cuts,

- ✓ Entrapments due to overturning of machines or vehicles,
- ✓ Entrapments by or between objects,
- ✓ Projection of fragments or particles,
- ✓ Falling objects being handled.

Listed below are some activities that must be carried out:

- Train workers in preventive matters, theoretically and practically, on the work equipment necessary for their job.

- Guarantee the conditions and correct way of using machinery, based on the manufacturer's instructions.

- Promote the consultation and participation of workers in aspects related to mechanical risks.

- Guarantee periodic monitoring of the health status of workers.

- In the event of accidents or occupational diseases due to mechanical risks, the necessary corrective measures must be investigated and applied so that it does not happen again.

Figure 2: Signs of mechanical risk

2. Introduction

Read carefully and comply with the indications given in this manual before intervening in the product, failure to comply with them invalidates the guarantee.

In certain oil market applications, a standard transformer cannot be used due to frequency drift, harmonic distortion, and the direct current component in the output voltage of the frequency converter.

The transformers used in this sector can be step-up or step-down and the most common applications are for oil extraction with electric submersible pumps and similar equipment in applications for high voltage motors.

Electrosubmersible pumping is an artificial lift system applied to move crude volumes with high efficiency and economy, in potentially profitable reservoirs (or failing that with great prospects) and in deep wells, in order to handle high flow rates.

This method is generally applied when the following cases occur:

- High productivity rate,
- Low bottomhole pressure,
- High water-oil ratio,
- Low gas-liquid ratio.

Electric submersible pumping is a system made up of two types of teams: bottom teams and surface teams.

The bottom equipment is the one that allows the extraction of crude through one or more centrifugal pumps coupled to one or more motors.

The surface equipments are those that allow to carry the electric power supply for the motor, configure the speed of rotation of the motors and with this the flow rate of crude oil extraction.

The equipment of interest to MAGNETRON S.A.S. is the surface equipment, this is where its application and use of the various types of transformers it manufactures will be deepened.

1. Electric power source.
2. Phase-shifting input transformer (step-down if the mains is 13200 – 13800V).
3. VSD 480V electronic frequency variator (6, 12, 18 and 24 pulses).
4. Variable Frequency Step-up Transformer (SUT).
5. Bottom equipment – Engine.

Figure 3: Type of electric submersible pumping system

From this surface equipment system, MAGNETRÓN S.A.S. manufactures transformers for the various configurations that this topology can take, placing special emphasis on input transformers or phase shifters, which must be of a specific type according to the type of VSD drive used and availability of electrical energy.

The motors used in this type of application are motors that operate at a voltage greater than or equal to 1100V with the aim that the currents that circulate through the power wiring are as low as possible; In addition, they have the ability to rotate at different speeds with which it is possible to adjust the flow rate with which the oil is extracted.

Special considerations:

2.1 SUT type transformers

It is the equipment in charge of supplying the voltage required by the motor according to the necessary conditions for the exploitation of the well, this contemplates that it be carried out at a certain speed and power. To operate in such conditions, the transformer must be designed in such a way that it complies with the following conditions:

- Variable frequency from 10 Hz to 90 Hz.
- Multiple output voltage possibilities, fine adjustment and coarse adjustment of the transformation ratio.
- K factor for the increase in losses due to the temperature of the windings due to the harmonic distortion generated by the VSD.
- Shielding and increase in insulation to support the VSD output voltage carrier signal.

Very important: In this type of transformers, the voltage/frequency (V/Hz) relationship must be taken into account. This data is found on the nameplate and refers to the variation that the SUT power supply voltage presents for each Hertz (1 Hz) that varies the frequency in the VSD.

In other words, this relationship indicates at what power frequency I get the voltage and nominal power of the SUT.

An example is given below with a SUT transformer, 480 V input voltage, and a V/Hz ratio of 10.67.

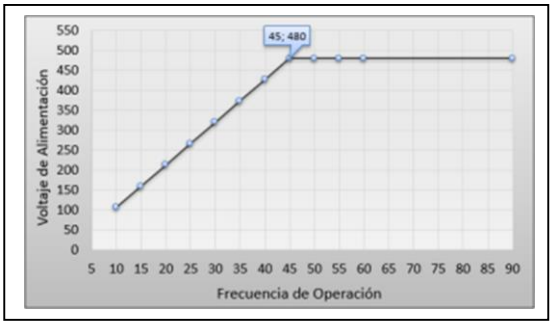


Figure 4: The graph indicates that, with 45 Hz, the VOLTAGE is obtained nominal at the input of the SUT, from then on, it is constant.

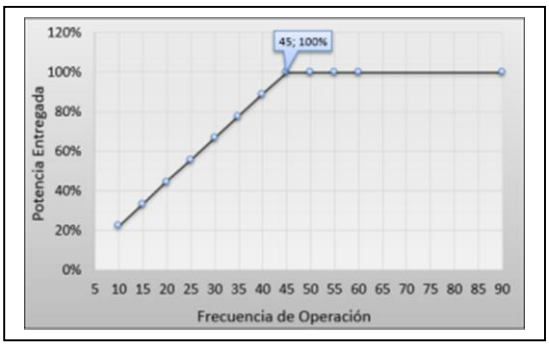


Figure 4-1: The graph indicates that, with 45 Hz, the nominal POWER of the SUT is obtained, from then on, it is constant.

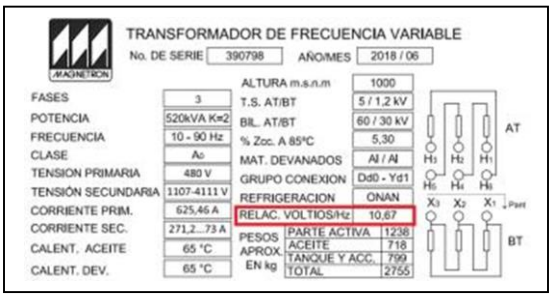


Figure 4-2: Example nameplate illustrating the V/Hz relationship

2.2 VSD frequency inverter

It is a solid-state electronic equipment that allows to vary the output voltage and frequency from the commutation of its components.

This commutation generates a harmonic distortion in the sine wave in the electrical network upstream and downstream.

These equipments have a range of operating voltage, although it is noteworthy that in their nominal characteristics they are 480V power supply at 60Hz, allowing a variation in their voltage and frequency output.

The number of VSD pulses in rectification and inversion determines the harmonic distortion characteristics, where a 24-pulse VSD handles a lower harmonic distortion rate than a 12-pulse VSD.

2.3 Input transformer (phase shifter)

Caution: MAGNETRON S.A.S. does not recommend the use of AUTOTRANSFORMERS where there is a restriction of harmonics in the network, since they do not filter them by presenting a single winding in their construction.

This equipment is selected according to the availability of electrical energy where it will be installed and the type of frequency inverter that must be fed. Usually, the output voltage of this equipment is 480V at 60Hz or 415V at 50Hz.

If the transformer is powered by an electric generator or step-down transformer, its input voltage will be 415/480V as well as its output voltage; If it is powered directly from the mains, this will be a step-down transformer with 13200 or 13800V input voltage and its output voltage will be 415/480V at 50/60Hz.

Also, according to the type of drive that it will feed, this transformer can be of a specific type in order to reduce the ammonium distortion generated by the VSD in the network.

If the drive is 12-pulse, a phase-shifting transformer of the following type can be used:

- Polygonal delta autotransformer (six output phases offset by 30° between them, 15° and -15° with respect to the input).

- Six-phase (six output phases, one LV in star connection (Y) and one LV in delta connection (D), the most common connection groups are Dd0, Dyn1 or Dyn5).

If the inverter has 18 pulses, it will be more efficient to use a phase-shifting transformer type:

- Nine-phase or 18 pulses, (nine output phases, one LV in Ddo connection and two LV with Dz connection and offset 20° and -20° with respect to the input).

If the drive to be used is 24 pulse, it will be more convenient to use a type transformer:

- Twelve-phase, this allows a more effective reduction of harmonics in the electrical network compared to other phase-shifting transformers.

  Twelve-phase (12 output phases, four LV in Dz connection with displacements 7.5°, 22.5°, -7.5° and -22.5° with respect to the input).

It is worth clarifying, with any of the types of drives it will be possible to use a phase-shifting transformer or not, but the use of an appropriate transformer for said VSD means a reduction in harmonic distortion and therefore a decrease in losses due to heating of the equipment, extending its useful life.

3. Definitions

3.1 Transformer

Electrical device without moving parts that transforms electrical energy into its two main factors: Voltage and Current.

3.2 Autotransformer

It is an electrical machine, of construction and characteristics similar to those of a transformer, but which, unlike it, only has a single winding around a ferromagnetic core.

In an autotransformer, a part of the winding is common to both the primary and the secondary.

3.3 Harmonic distortion

Broadly speaking, they are disturbances in the real frequency of the electrical signal that originate within the facilities.

Harmonics generate voltage drops, causing all kinds of problems in the short or long term.

3.4 K-factor:

It is an indicator that allows estimating the capacity of a transformer to withstand the thermal effects generated by harmonic currents without exceeding its operating temperature.

3.5 Primary winding

Winding that is connected to a power source.

3.6 Secondary winding

Winding to which a load is connected.

3.7 Medium voltage winding

Winding with the highest voltage.

3.8 Low voltage winding

Winding with the lowest voltage.

3.9 Packaging

Fabricated deck usually in wood in which transformers are packed during storage and transport.

3.10 Packing basis

Flat and strong structure made of wood or metal that serves to protect and support the weight of the transformer.

3.11 Danger

Inherent situation with the capacity to cause injury or damage to people's health.

3.12 Risk

Combination of the probability that a dangerous event will occur with the seriousness of the injuries or damage to health that such an event can cause.

4. Abbreviations

A	Amps
AGD	Dissolved gas analysis (DGA)
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
MV	Medium voltage
LV	Low voltage
DPS	Device for surges (lightning rod)
Hz	Frequency (Hertz)
IEEE	Institute of electrical and electronic engineers
kg	Kilogram
kV	Kilovolt
kVA	Kilo volt amps
lbf.ft	Pound-force foot
m	Meter
max	Maximum
min	Minimum
mΩ	Milliohms
MΩ	Megohms
ms	Milliseconds
NTC	Colombian technical standard
PCB`s	PCBs
PN	Neutral point
psi	Pounds forcé per square inch
PST	Phase shift transformer
PTS	Grounding system
SUT	Step up transformer
Grd	Grounding
TTR	Transformer turns ratio
V	Volts
VSD	Variable speed drive
VSP	Overpressure valve

5. Handling

Caution: The transformer must be handled in a vertical position.

Caution: The information, recommendations, descriptions and safety notes compiled in this document are based on guides, standards and the experience of MAGNETRON S.A.S.

Caution: This information does not include or cover all contingencies, therefore, if you require more information, contact MAGNETRON S.A.S.

Keep the transformer on the base (wooden or metal) on which it is shipped to the place where it will be installed, as this provides greater protection.

Also, it can be kept on the casters or in the crate (if it has one).

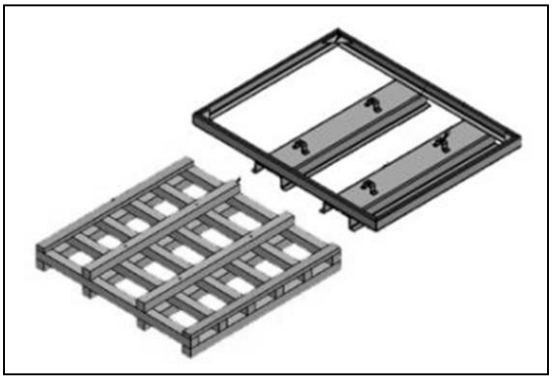


Figure 5: Bases used

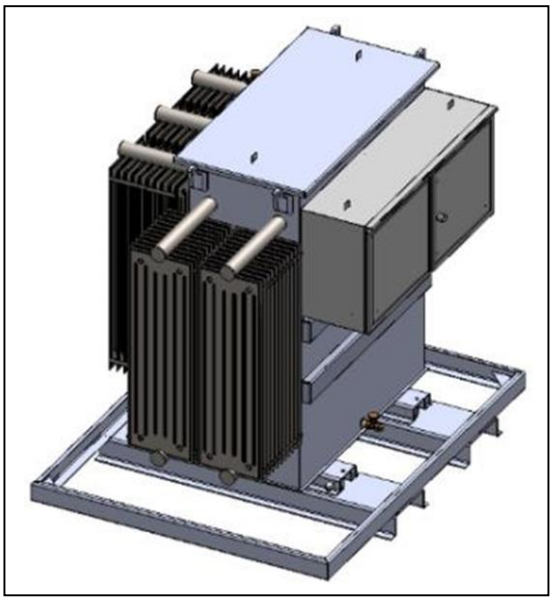


Figure 6: Transformer on base

For no reason allow the transformer to be dragged directly on the floor, the tank or the cabinet, they may suffer deformations or the paint could deteriorate, giving rise to the oxidation of the sheet.

The transformer should only be lifted or hoisted using the four (4) lifting lugs; to transport it, use forklift or crane.

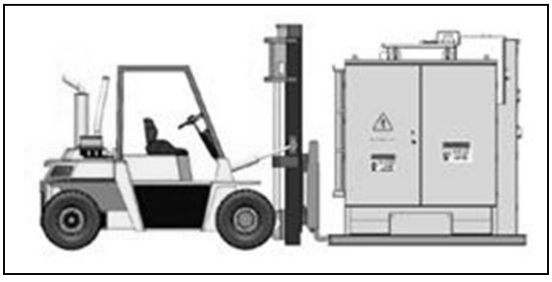


Figure 7: Transportation with forklifts

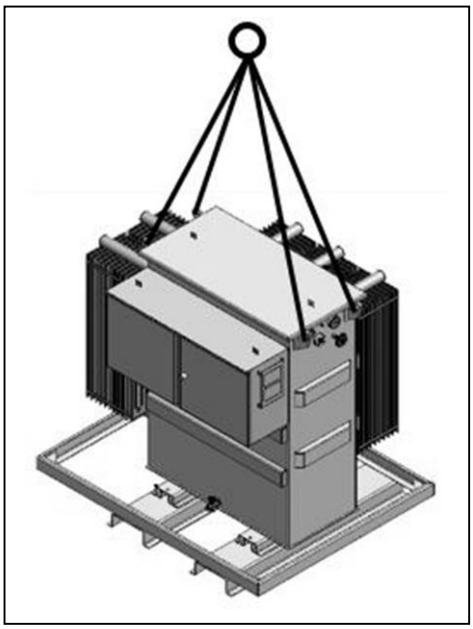


Figure 7-1: Lifting by Lifting Lugs

Do not lift or move the transformer by placing crowbars or jacks under accessories, connections, radiators or other devices, since these elements are not designed to be subjected to this type of stress and may break or deform, causing leaks of insulating liquid.

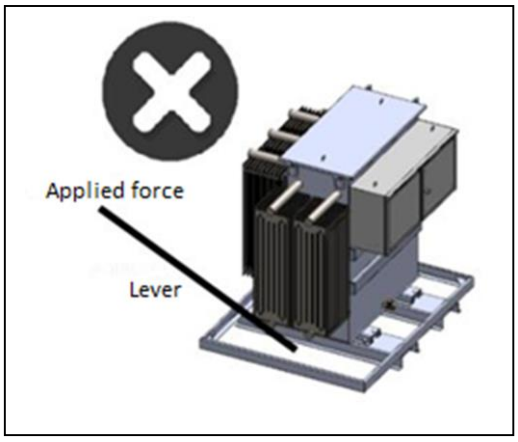


Figure 8: Improper handling

When a transformer cannot be handled by means of a crane, differential, forklift or stowage carrier, it can be moved by sliding it on skids or rollers.

Use rollers or skids according to the weight of the transformer and in sufficient quantity to distribute its weight.

Don't let it tip over (it may tip over); besides, be careful not to damage the base and put pressure on the cabinet.

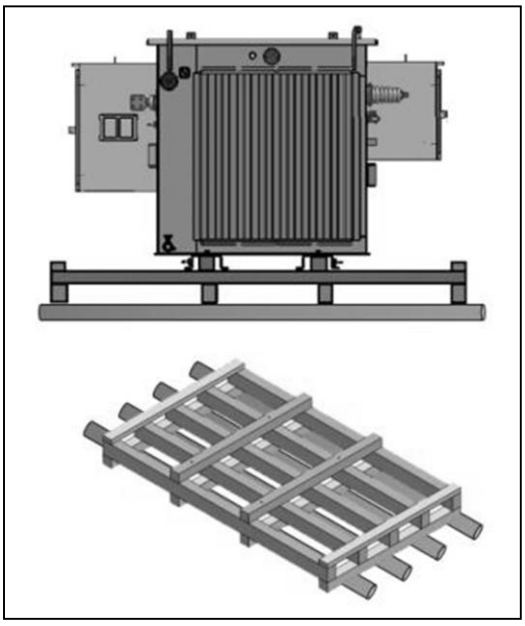


Figure 9: Use of rollers or skids for transportation

The transformers are provided with lifting devices or lifting lugs that are used to handle it with a crane, use fiber slings as these help protect the paint.

If you use strings or metal slings, be sure to cover the parts in contact to avoid paint detachment.

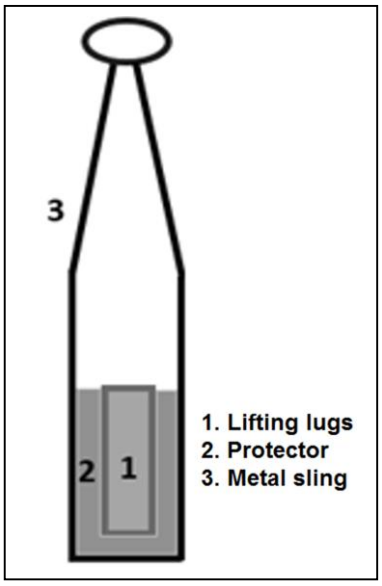


Figure 10: Paint protection on the lifting lugs

Do not use the lifting lugs to transport the transformer, they are designed for lifting or hoisting only.

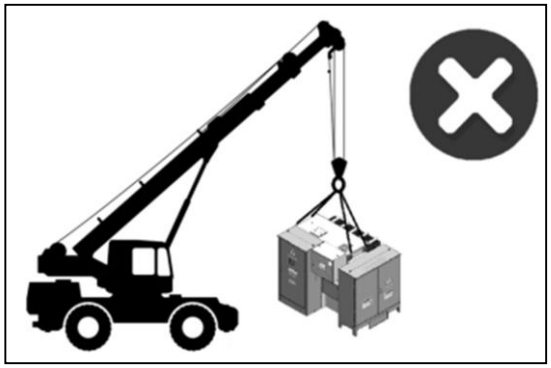
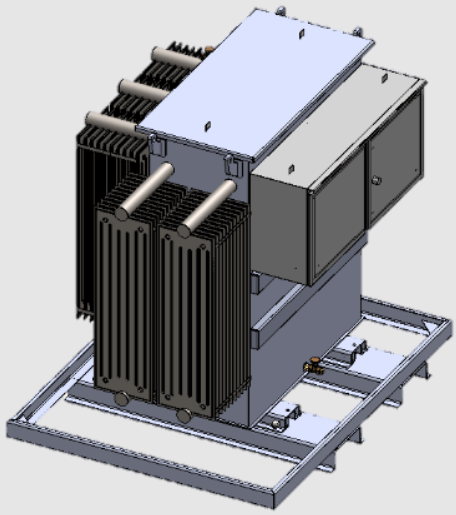


Figure 11: Transport of the transformer by the lifting lugs is prohibited

Caution: For no reason should it be supported or stopped on the transformer cabinets, LV terminals, MV insulators, drain and recirculation valves or any control or protection element.



6. Packaging

The transformer packaging must allow handling in such a way that, when any movement is required for its storage or transport, it can be easily lifted by the base of the packaging.

The base of the packaging must have a minimum height of 10 cm to allow the entry of a forklift or a dunnage carrier.

The wooden bases are designed so that they can be manipulated from the front, the back or the sides.

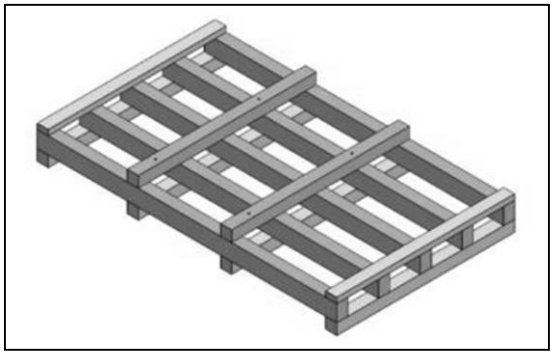


Figure 12: Wooden base for power transformers

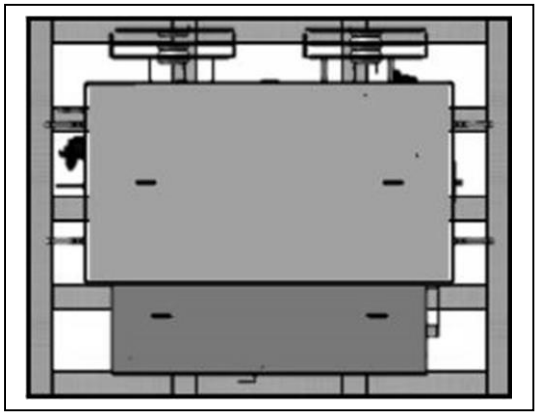


Figure 12-1: Wood Base Transformer – Top View

The metal bases are designed in two models:

- For handling from the front or rear, when the base does not exceed 2200 mm in length.
- Other for handling from the sides, when the base exceeds 2200 mm in length.

Note: The metallic bases are used in transformers with weight ≥ 4000 kg or by customer request.

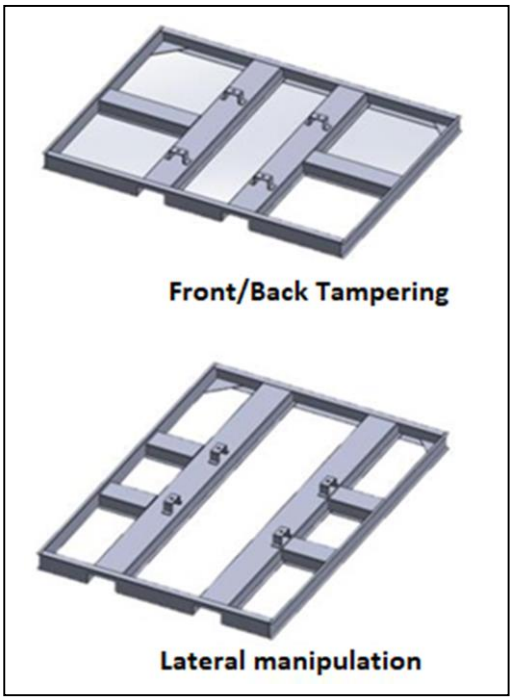


Figure 13: Metal base for power transformers

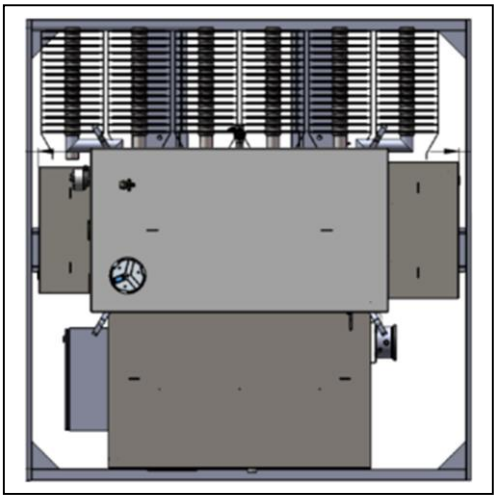


Figure 13-1: Metal Base Transformer – Top View

For transformers that must be lifted or transported by crane (by weight or size) and that are boxed, it must be ensured that the lifting lugs remain free and easily accessible for the location of the slings or slings.

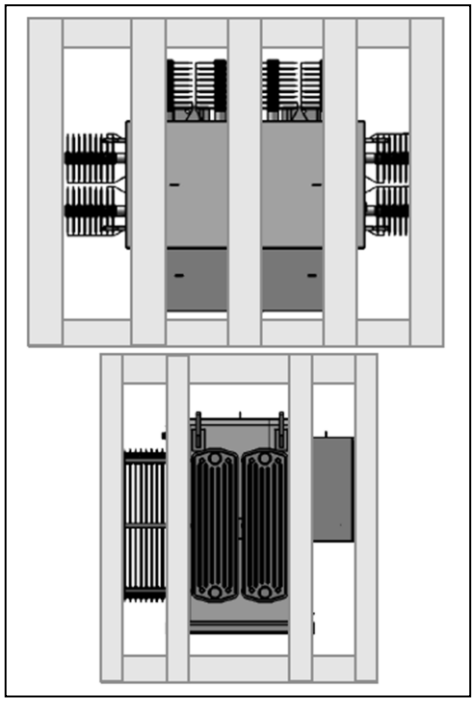


Figure 14: Easy Access Lifting lugs

The transformer must be attached to the base of the packaging, to prevent it from suffering deterioration caused by sudden movements. In this type of transformers, the coupling is done through of screws.

Figure 15: Anchoring the transformer to the base with screws

When the transformer is shipped boxed, the nameplate must remain visible to validate the characteristics of the transformer.

If the transformer consists of one or more cabinets and the nameplate is inside one of them, for identification, locate the serial number attached to the cabinet cover in the upper right part of the front, you can also check the kVA (if applicable) on the same front.

The location of the sticker with the serial number may vary depending on the configuration of the transformer.

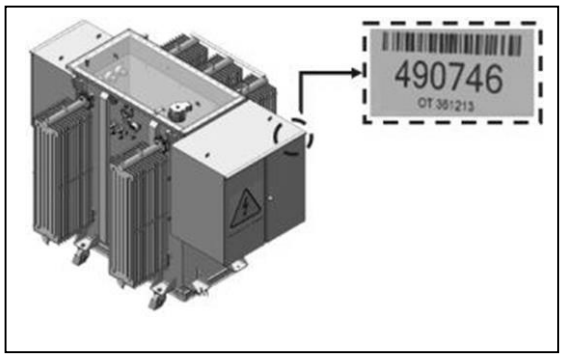
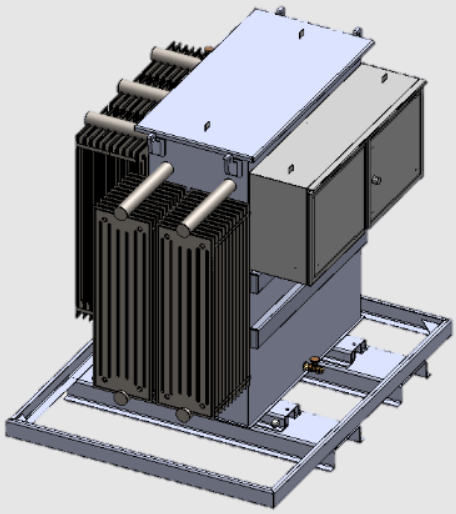


Figure 16: Serial number sticker

Caution: For no reason should it be supported or stopped on the transformer cabinets, LV terminals, MV insulators, drain and recirculation valves or any control or protection element, these elements are very fragile and can easily be damaged.



7. Transport

In order to guarantee the transport and final delivery of the equipment, it is very important to take into account the following:

- The commercial conditions,
- Road conditions,
- The final place of delivery,
- The height of the load,
- The weight of the load,
- The final dimensions.

Take into account the weight of the transformer to determine the appropriate lifting and/or transport elements, this information appears on the nameplate, in the test certificate or in the documents required for its transport.

Lift the transformer using the lifting lugs or the base of the packaging.

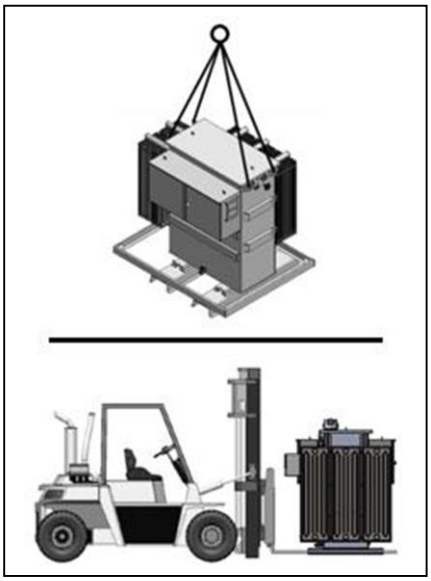


Figure 17: Parts to lift the transformer.

When lifting the transformer from the lifting lugs, be sure not to rub or touch any component (fixtures, cabinet, etc.) with the slings or slings.

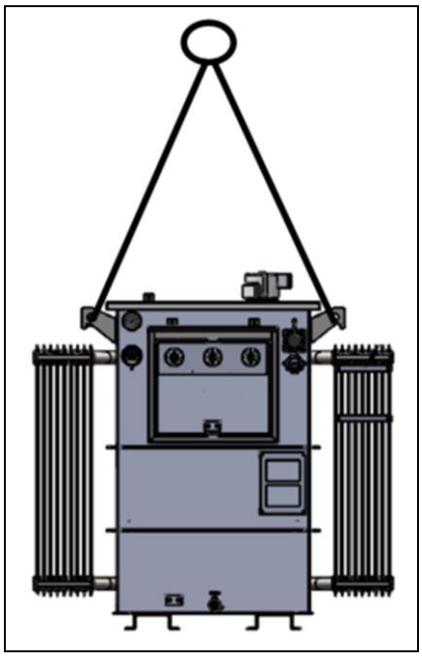


Figure 18: Elevation of the transformer from the lifting lugs

7.1 Load distribution:

7.1.1 Transformers without crate

When a considerable number of transformers are transported, the load must be distributed within the truck or container.

The base of the transformers acts as a separator, when there are spaces between them, wooden wedges must be fixed between them and the floor.

The function of the wooden wedges is to prevent displacement

of the transformers when the transport is in motion.

Additionally, transformers must be slinged to the walls of the truck or container and to each other.

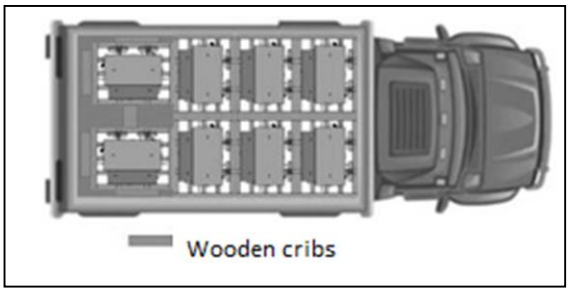


Figure 19: Loading, distribution and use of chocks

When few units are charged due to the size of the product, please note the following:

- The load must be placed centered on the bed of the truck or container.
- If the product has radiators, load them interleaved in the truck or container, this ensures that the load is balanced.
- When the base of the transformer and the floor of the truck are metallic, wooden boards must be located between them to avoid displacements.

In addition, if the base of the transformer is metallic, it must also be tied to the truck body.

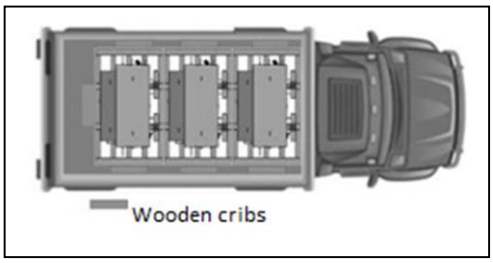


Figure 20: Centered load

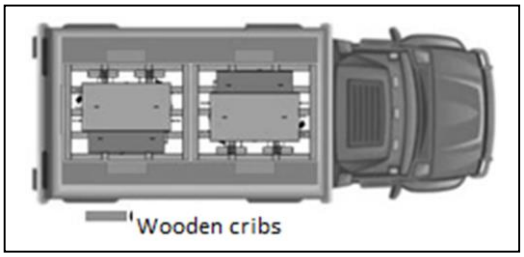


Figure 21: Interleaved radiators

Figure 22: Wooden boards between the metal base of the transformer and the metal floor of the truck

7.1.2 Transformers with crate

These transformers are loaded and transported following the same considerations as transformers without crate. However, the following observations are made:

- The packaging (base and crate) of the transformers acts as a separator, when there are spaces between them, wooden wedges must be fixed between them and the floor.

- These transformers can be loaded on up to two levels, as long as the weight of the load located on the second level does not exceed 400 kg.

  Additionally, each set must be tied together to form a solid unit and between them to the walls of the truck or container.

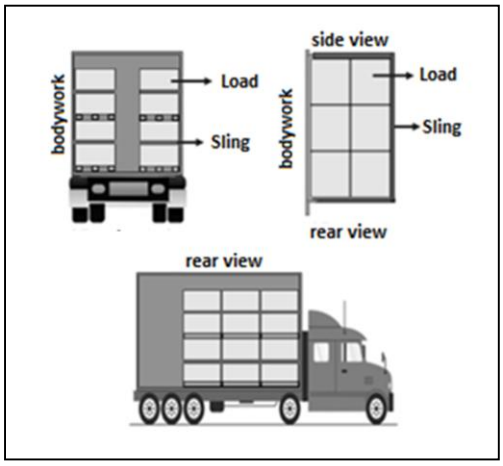


Figure 23: Correct way of loading and lashing crated transformers

- The lashing of the load to the body of the truck or container can be done in various ways:

- Passing the sling over the crate.

- Passing the sling over the cover and the transformer cabinet.

- Passing the sling over the transformer lifting lugs.

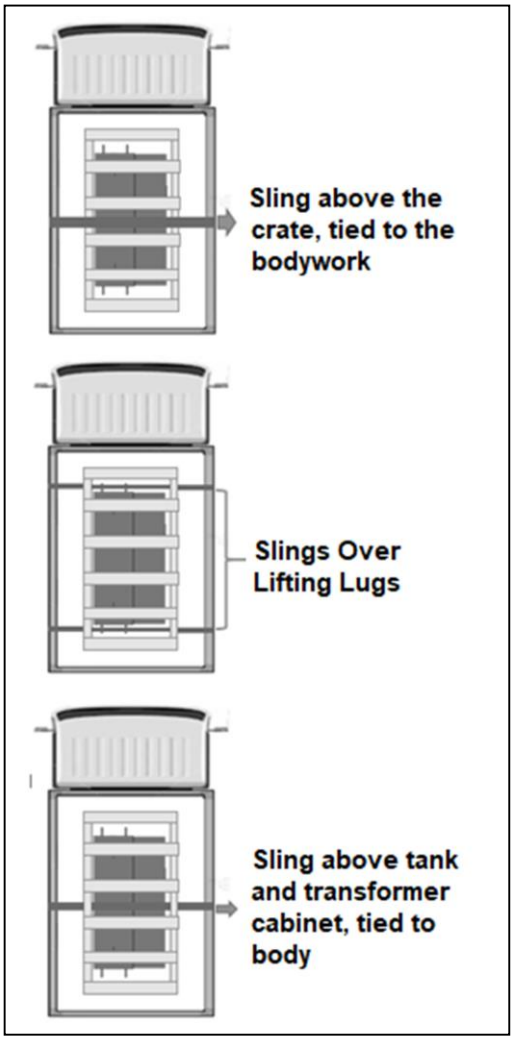


Figure 24: Ways to tie the packed cargo to the truck or container

7.1.3 Load open top trucks

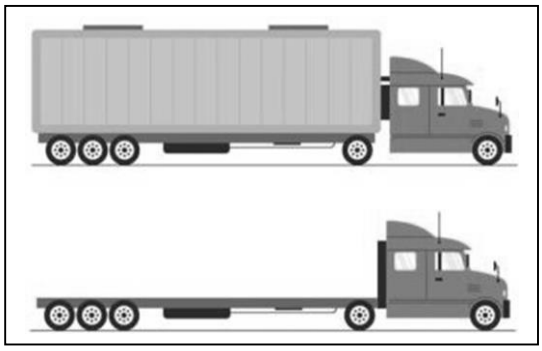


Figure 25: Normal and convertible truck

This type of loading is done at the request of the client or due to the dimensions of the product to be transported.

Loading on this type of truck has several advantages:

- By not having the tent, the rod and the sides, better use is made of the total available area of the plate.
- Applies to transformers with or without crate.
- The load can protrude +/- 15 cm from the sides of the plate.

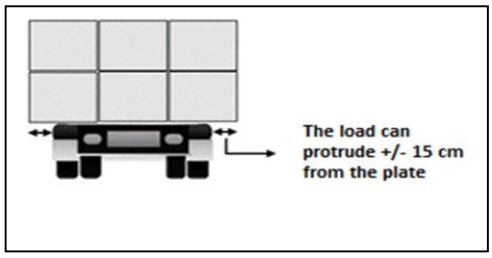


Figure 26: Load tolerance on the sides of the plate

- The total number of transformers in the load is increased.
- The loading and unloading is done by the sides of the truck, reducing the time of these operations.
- When loading created transformers, they can be stacked up to two levels, as long as the weight of the transformers on the second level does not exceed 400 kg.

Caution: For Colombia, the total height of the load, measured from the floor, cannot exceed 4.3 m.

The total weight of the load cannot exceed the capacity of the truck.

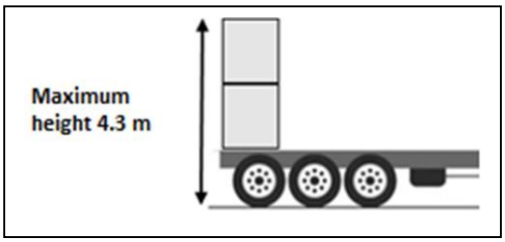


Figure 27: Maximum height of the load

➢ Steps for loading

- Loading must be done from the front of the plate (near the cabin) to the back of it.
- With the help of the appropriate mechanical means (forklift, crane, etc.) load the first transformer, it should be centered on the truck bed.

- Repeat the previous numeral until completing the total load of the truck.

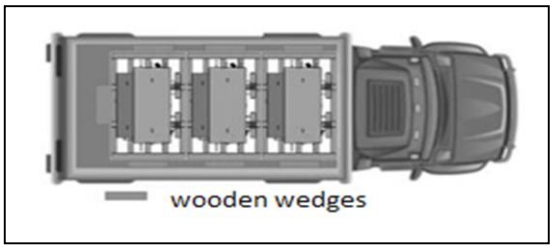


Figure 28: Centered load

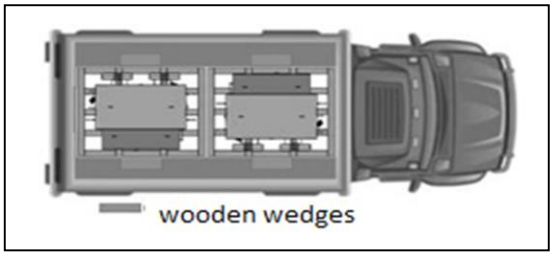


Figure 28-1: Interleaved radiators

- Once the transformers are located and aligned on the platform, secure them with slings to the truck chassis (see, for help, figure 23 of number 7.12).

Figure 29: Lashing cargo with slings

- To prevent shifting of the load during transport, secure the last loaded transformer with a sling.

Figure 30: Securing the last row of loaded transformers

Precautions: All rows must be secured with slings, these must be well tensioned.

If you use strings or metal slings to lift the transformer, be sure to cover the parts in contact to avoid paint detachment.

7.1.4 Open top loading unit (container without roof)

When loading this type of container, keep the following in mind:

- Use bridge crane (differential) or crane.
- When lifting the load, do so only until it exceeds the height of the container (lifting it excessively can cause accidents).
- Be sure not to hit the charging unit.

- The cargo cannot stick to the container walls.
- Check the condition of the slings, straps or shackles, do not use them if they show damage or deterioration.

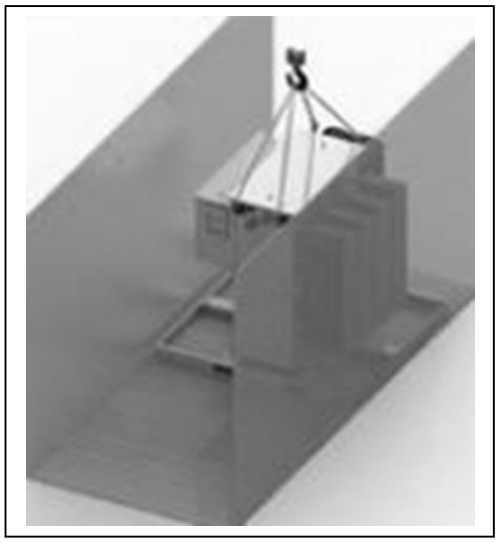
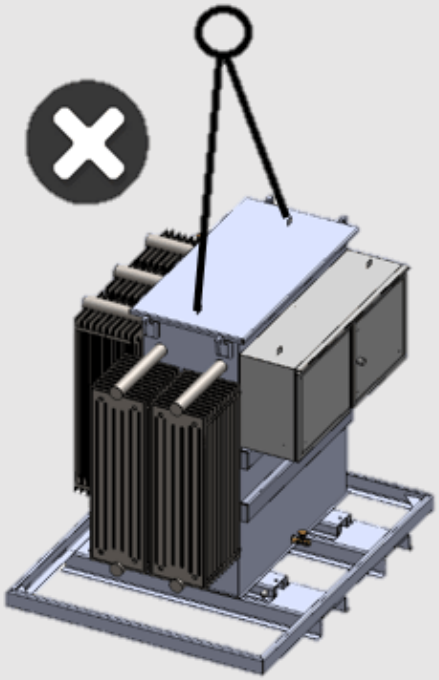


Figure 31: Load container without roof

7.1.5 Download

Precautions: Some transformers have lid lifting attachments, NEVER use them to lift or hoist the transformer.



If you use strings or metal slings to lift the transformer, be sure to cover the parts in contact to avoid paint detachment.

The unloading of the transformers is the responsibility of the customer, unless otherwise specified in the contract. However, the following should be noted:

- Always use the appropriate mechanical means, forklift, crane, etc.
- The mechanical means used must have at least twice the

capacity of the weight of the transformer.

- Lift the transformer only by the lifting lugs or the bottom of the packaging.
- Personnel involved in the discharge must stay away from the transformer when it is elevated.
- Transformers loaded in open-top trucks must be unloaded inversely when loaded.
- In containers or trucks with the body installed, the transformers that are out of reach must be pulled until they are placed in the unloading position, to do this:
    - Attach a sling to the hoist or mechanical means used and pass it around the base of the transformer packaging.

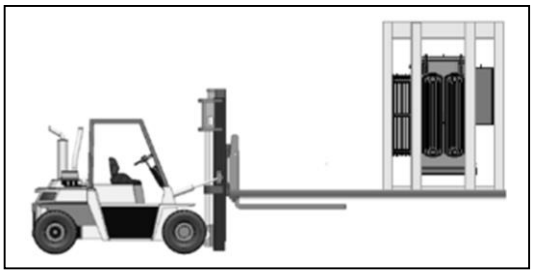
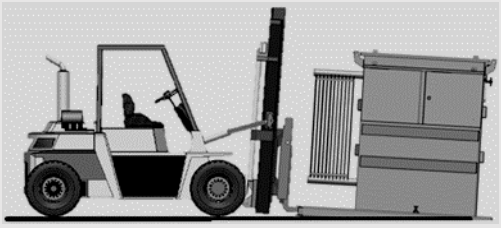


Figure 32: Proper way to pull a transformer on discharge.

- Pull the transformer until it is within reach of the mechanical means used.
- Download the transformer.

Precautions: The transformer should not be moved using drag support or lashing to the tank.



8. Reception

Caution: Before discharging the transformer, should visually inspect the state of the same, any abnormality communicate it to the transporter and leave a record of it.

The transformers covered in this manual are factory tested according to standards, they are delivered fully assembled and ready for installation or disassembled according to their size and weight, however, taking into account the difficulties that arise during transport, the following should be taken into account:

- Check that the security seals located between the lid and the tank for the national product have not been removed or show evidence of having been tampered with.

Figure 33: Security Seal

- Check that the security seals located in places that have removable parts (junction boxes, hand holes, bolted covers, etc.) for the export-type product, have not been removed or show evidence of having been tampered with.

Figure 34: Security seal on removable parts

- When the transformers are dispatched and transported in several sections such as: The main tank, the insulating liquid, the radiators and other elements; Disassembled components are packed in crates or boxes and must be checked against the supplied packing list.
- Check the state of the medium and low voltage insulators, they should not be loose or present damage.
- Check the state of the control instruments that are attached to the main tank.
- Check the state of the tank, it should not show bumps, cracks or damage to its paint.

- Check that caster wheels (if fitted) arrive with the transformer.

Figure 35: Caster wheels

- Check that there are no insulating liquid leaks.
- Check that the hardware is not loose or out of adjusment.
- Inspect the base of the packaging, it should not show damage.
- Check that the characteristics of the transformer correspond to what was requested (power, phases, voltages, serial number, etc.).
- In case of finding damage to the transformer, if possible, leave a photographic record of the findings.
- Inform the transporter of the abnormalities found.
- Contact MAGNETRON S.A.S. and notify what happened supplying the complete information of the transformer.
- Keep in mind what is established in Transportation (numeral 7) before unloading the transformer.

9. Storage

Caution: Keep the transformer in the packaging (base or crate), this protects it from damage or deterioration during storage.

Caution: To prevent moisture from entering the transformer, the overpressure valve MUST NOT be actuated for any reason.

Once the transformer has been delivered to the customer, it is advisable to place it in its permanent location, even if it is not put into operation immediately. If this is not possible, locate it in a dry place; Also, you should fill it with insulating liquid if applicable.

Abide by the following instructions to ensure its good condition:

- Store it indoors.

  Note: If storage is done outdoors, keep in mind that environmental conditions can deteriorate the wooden base or the transformer crate, thereby causing damage or deterioration thereof.

- When applicable, power the control cabinets at their corresponding voltage to avoid water condensation inside.

- When storage is extended for more than six (6) months, has to periodically inspect the state of the wooden base or the crate.

- Do not store it in places where there is presence of moisture, sludge, corrosive gases or explosive atmospheres.

- Transformers received in multiple sections must be fully assembled, topping up the insulating liquid level, and pressurize the tank with dry nitrogen at 3 psi.

  Note: If it cannot be fully assembled, the parts and pieces must be kept sealed to prevent moisture penetration.

10. Basic accessories

Caution: If any accessory is not covered in this manual or requires more information, contact MAGNETRON S.A.S.

The accessories installed in this type of transformers can be classified into two (2) types:

10.1 Normal accessories

Minimum required elements, supplied by the manufacturer with the transformers, useful for their identification, handling, installation, proper functioning and protection.

- Low voltage bushings.
- Medium voltage bushings.
- Tank grounding device.
- Steerable wheels.
- Devices for hydraulic jack.
- Devices for lifting or hoisting the complete transformer.
- Device to lift or hoist the active part and the cover.
- Valve for taking samples of the insulating liquid.
- Valves for recirculation and drainage of the insulating liquid.
- Insulating liquid level indicator.
- Thermometer pocket.
- Dial thermometer with or without contacts.
- Overpressure relief device with or without contacts.
- Labeling of the MV and LV Bushings.
- Rating plate.
- Non-voltage tap changer.
- Terminal box for instrument signals.
- Electrical connection between assembled metal parts of the tank.

10.2 Optional gadgets

Other additional elements supplied by the manufacturer with the transformers, at the client's request.

- Thermal image for simulation of the temperature of the windings and/or control of forced ventilation.
- Swivel wheels with flanges for rail and brake device.
- Ski or skate type base to drag the transformer on the floor.
- Supports for lightning rods.
- MV and LV hub protection boxes.

10.3 Accessories illustration

Some of the accessories used in the transformers that are the subject of this manual are detailed below.

10.3.1 MV bushing

Accessory, normally made of porcelain, designed to mechanically hold the conductors that are part of the power line, keeping them isolated from earth and other conductors.

Its main function is to make the bridge between the medium voltage terminals of the active part and the power supply.

Its characteristics vary according to the voltage level of the transformer, the basic level of insulation and the creepage and arc distances.

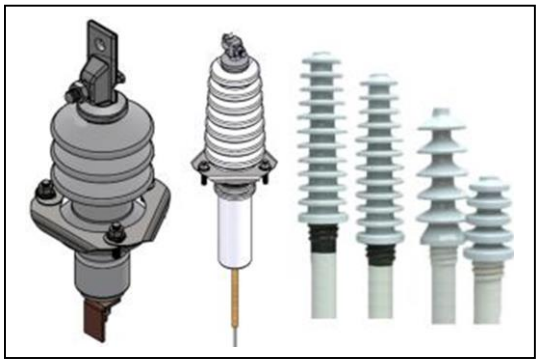


Figure 36: MV Bushings and some terminals

10.3.2 LV bushing

Accessory, normally made of porcelain, designed to mechanically hold the conductors that are part of the power line, keeping them isolated from earth and other conductors.

Its main function is to make the bridge between the low voltage terminals of the active part and the external load.

Its characteristics vary according to the voltage level of the transformer, the basic level of insulation and the creepage and arc distances.

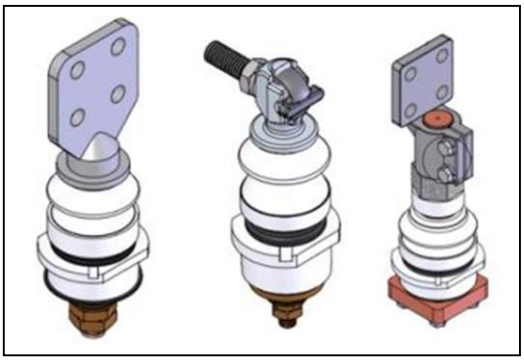


Figure 37: LV Bushings with their respective terminals

4.1 Overpressure valve

Its main function is to limit the internal pressure of the transformer when it is affected by its operating temperatures, directly associated with the installed load. The pressure relief valve is a means to relieve abnormal pressures that occur inside the transformer.

The relief valve must have a suitable gas evacuation capacity for the volume of the transformer.

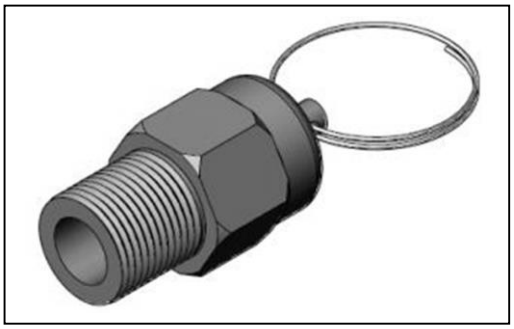


Figure 38: Overpressure valve

10.3.3 Tap changer

Caution: The switch has an external handle, which must be operated only with the transformer de-energized.

The switch performs voltage regulation, which consists of compensating for voltage variations that are detected at the receiving points of a power transmission or distribution system, varying the ratio of turns in the primary winding until the required voltage is obtained in the secondary.

There is a wide variety of switches used in transformers for the oil sector, two types are identified below:

- Circulars (3 bodies)
- Linear

10.3.3.1 Steps to operate the CIRCULAR tap changer

- Disconnect the transformer from the power source.
- Verify the absence of voltage on the transformer by measuring the LV winding with a voltmeter.
- Ground the MV and LV terminals.
- Using a screwdriver, loosen the handle anchor screw until it protrudes from the disc.
- Rotate the handle and bring it to the desired position.
- Re-secure the handle anchor screw, until it enters the disc.
- Remove the grounding connections from the MV and LV terminals.
- Measure continuity at the MV terminals to ensure that the switch is properly engaged.
- Re-energize the transformer.
- Measure the voltage on LV, confirm that it is the desired voltage.

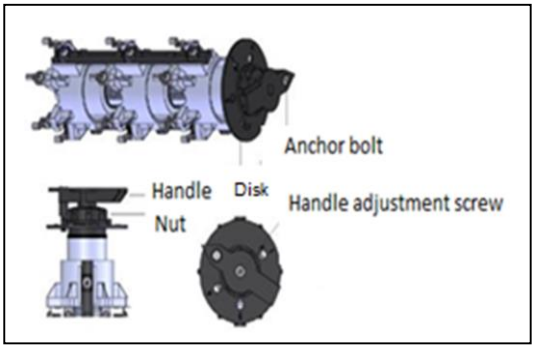


Figure 39: Circular tap changer

10.3.3.2 Steps to maneuver the LINEAR tap changer

- Disconnect the transformer from the power source.
- Verify the absence of voltage on the transformer by measuring the LV winding with a voltmeter.
- Ground the MV and LV terminals.
- Pull the knob until it is released from the disc anchor.
- Turn the knob and bring it to the desired position.
- Make sure the knob anchors properly on the disc.
- Remove the ground connections from the MV and LV terminals.
- Measure continuity at the MV terminals to ensure that the switch is properly engaged.
- Re-energize the transformer.
- Measure the voltage on LV, confirm that it is the desired voltage.

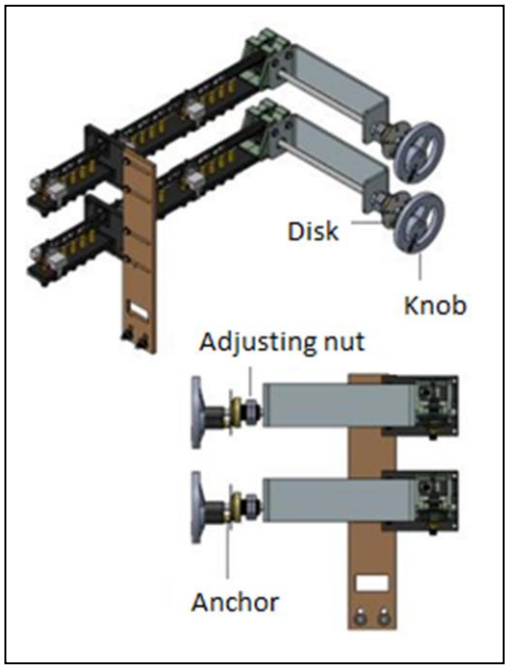


Figure 40: LINEAR tap changer

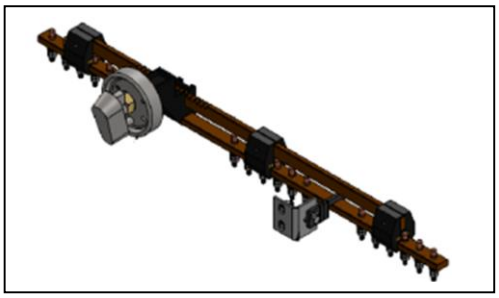


Figure 40-1: Linear tap changer

10.3.4 Nameplate

It is an accessory made of a material resistant to corrosion (aluminum, stainless steel, etc.) where the most relevant information on the transformer is recorded.

The plate must be affixed in a visible place and its inscriptions must be legible and indelible.

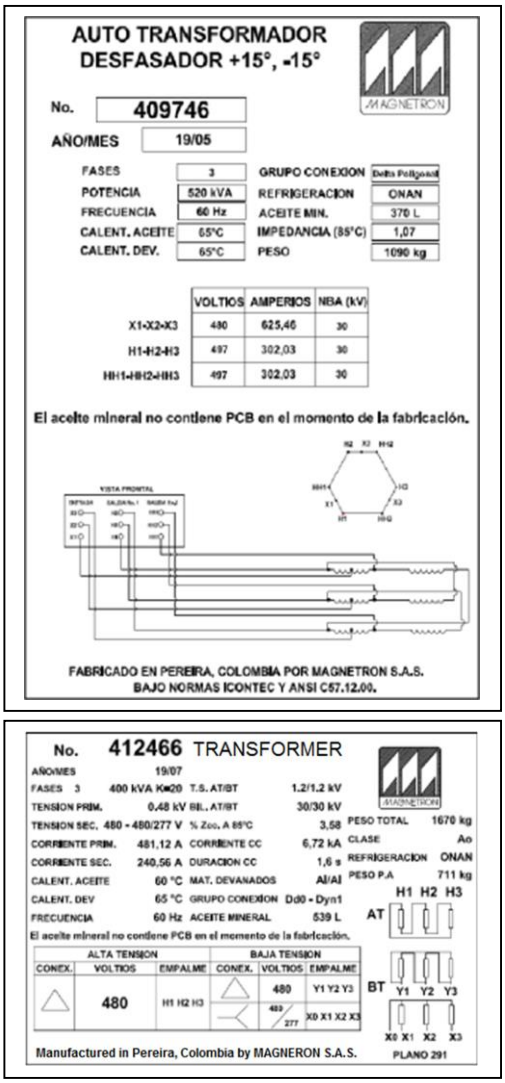


Figure 41: Example nameplates

10.3.5 Grounding system

The transformer is provided with screws (studs) or plates with their respective accessories to allow:

- The grounding of the LV or MV neutral point to the tank is shipped connected from the factory.
- The grounding of the tank to the grounding system where the transformer will be installed.
- The landing of the electrostatic screen, when the transformer has it.

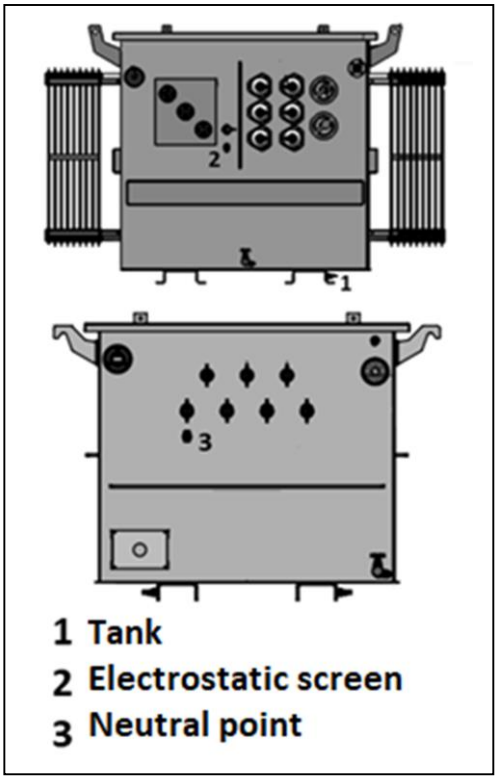


Figure 42: Grounding points

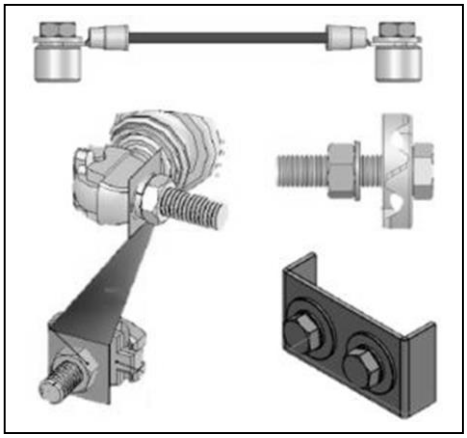


Figure 42-1: Accessories for grounding

10.3.6 Lifting lugs

Devices for lifting or hoisting the fully assembled transformer and filled with insulating liquid, are located in such a way that when hooking the straps or slings they do not lean against other accessories, nor against the bushings, nor do they damage the cover.

They are only used for hoisting or lifting, they are not for transporting.

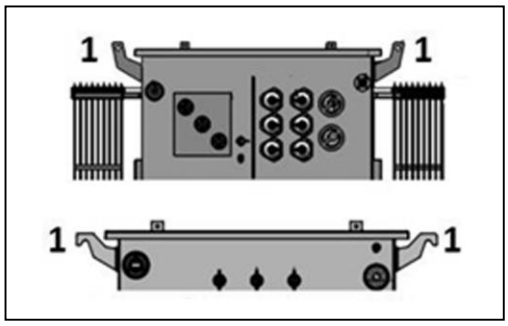


Figure 43: 1. Lifting lugs

10.3.7 External indication of the insulating liquid level

It is a device or meter that indicates the level of dielectric fluid in the transformer tank.

When the gauge is installed at the factory, the tank is filled to the level that corresponds to a liquid temperature of 25°C.

If the meter indicates a "LOW" liquid level, then the transformer should be de-energized and inspected to determine the cause of the low liquid level.

A low level of liquid can cause dielectric failure, overheating of the transformer and a reduction in its useful life.

As an optional feature, the liquid level meter can be provided with one (1) or more contacts for remote signaling of levels (low or high) of dielectric fluid.

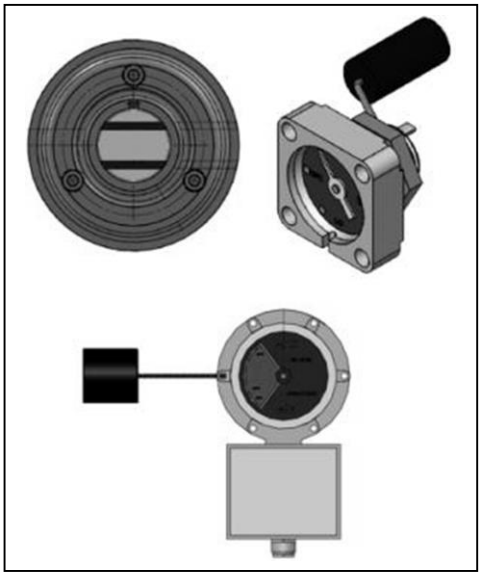


Figure 44: Insulating liquid level indicators

10.3.8 Temperature indicator (thermometer)

It is an instrument that measures the temperature of the liquid in degrees Celsius and includes a resettable maximum temperature indicator.

The red maximum temperature indicator can be reset by turning the magnet in the center of the faceplate towards the white indicator pointer.

The temperature gauge is mounted in a liquid-tight drywell for easy replacement.

As an optional feature, liquid temperature indicators can be provided with one (1) or more contacts to allow remote signaling of unacceptable temperatures or to control cooling fans installed on the transformer.

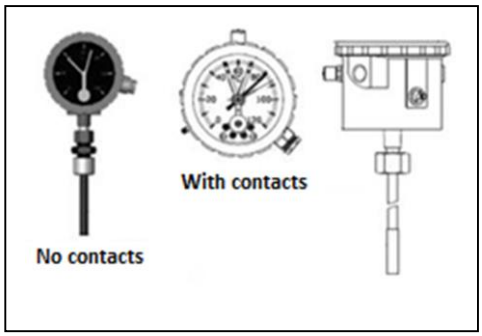


Figure 45: Temperature indicator

10.3.9 Drain valve

This device is located at the bottom of the tank, it is used for:

- Take samples of the insulating liquid in order to carry out tests.
- Drain the insulating liquid if necessary.
- Recirculate insulating liquid when performing field maintenance.

10.3.10 Recirculation valve

This device is located in the upper part of the tank above the level of the insulating liquid, it is used for:

- Fill the transformer with insulating liquid.
- Recirculate insulating liquid when performing field maintenance.
- Change the insulating liquid without taking the transformer out of service.

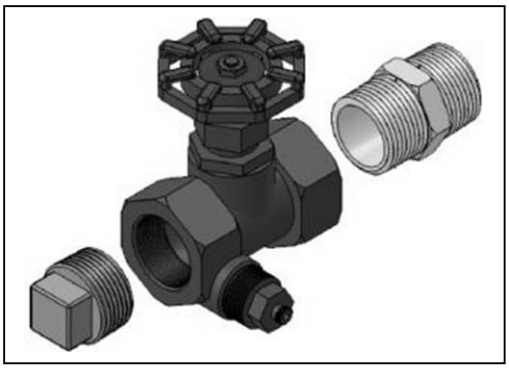


Figure 46: Drain or recirculation valve

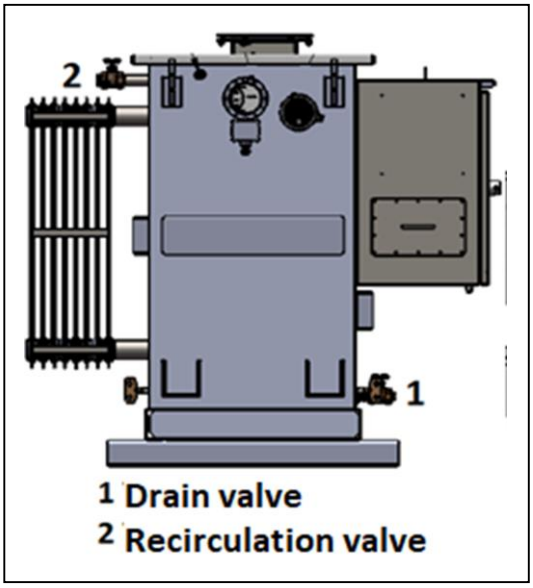


Figure 46-1: Location of valves

10.3.11 Lid lifting devices

Devices located on the cover that serve to lift or raise the cover, are not designed to lift the transformer.

When the active part is attached to the cover, these ears are designed to lift the COVER-ACTIVE PART assembly.

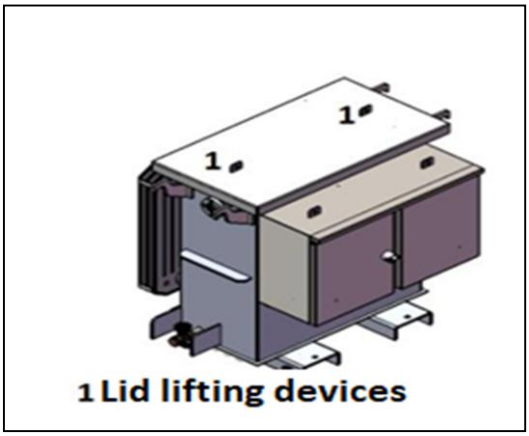


Figure 47: Lid lifting devices

10.3.12 Manovacuometer

It is an instrument designed to measure pressure, it is normally calibrated for in psi.

Its main characteristic is that it unites the functions of a pressure gauge and a vacuum gauge, since it is in charge of measuring both the relative pressure and the vacuum pressure.

Gauge readings should vary as transformer temperature changes and should normally indicate positive pressure.

Figure 48: Manovacuometer

10.3.13 Nitrogen filling valve (worm type)

It is a device used to fill the air chamber of the transformer with nitrogen.

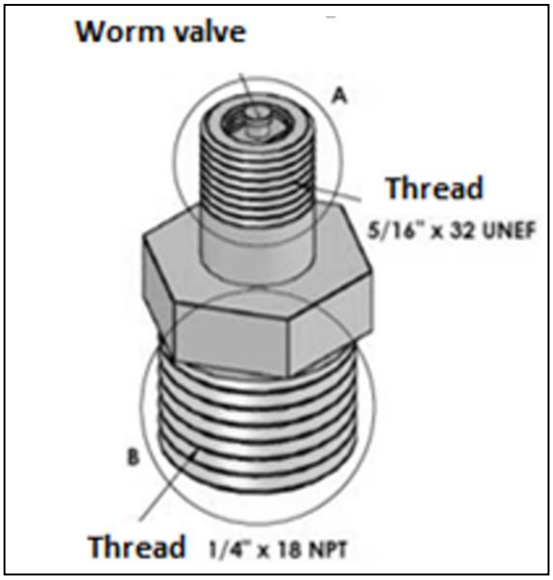


Figure 49: Worm type valve

11. Terminal markings

The marking of the medium voltage and low voltage terminals in this type of transformers are carried out according to the ANSI standard.

11.1 PST (Autotransformer) marking

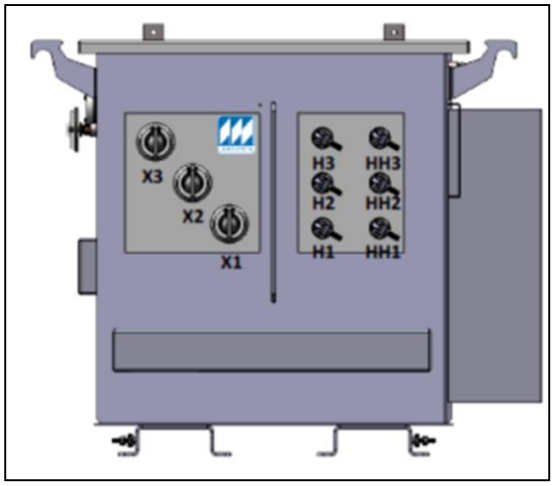


Figure 50: PST dialing

11.2 SUT marking

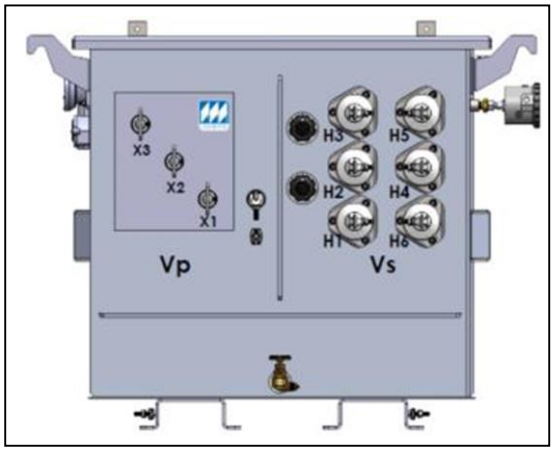


Figure 51: SUT dialing

11.3 PST (Hexaphase) marking

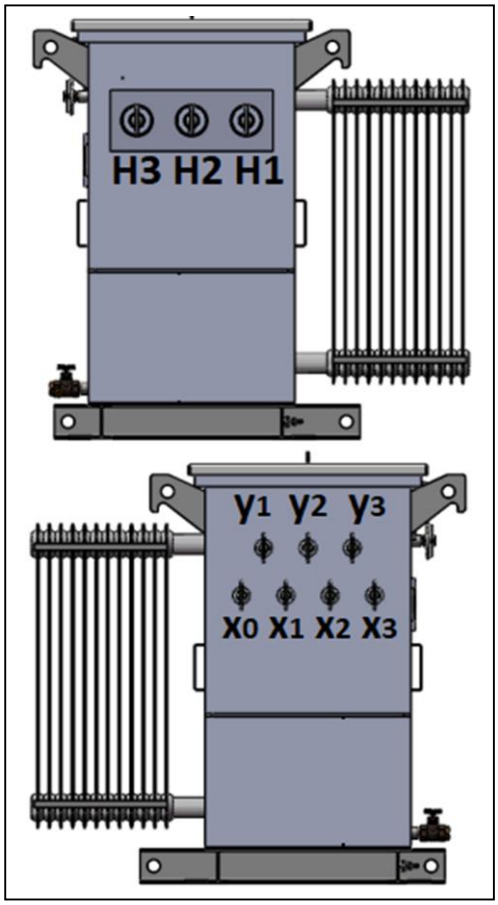


Figure 52: Hexaphase marking

11.4 PST (Dodecaphasic) marking

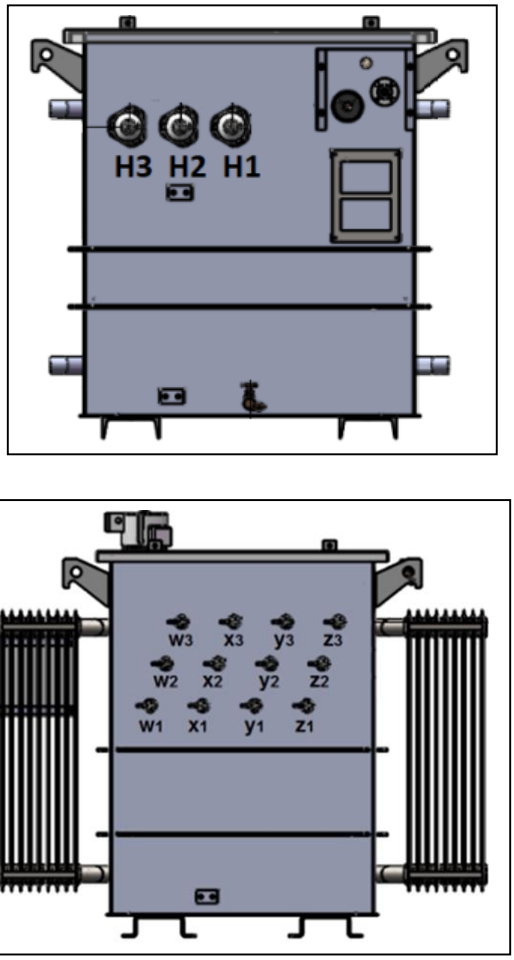


Figure 53: TWELVE PHASE marking

11.5 PST (Nonaphasic) marking

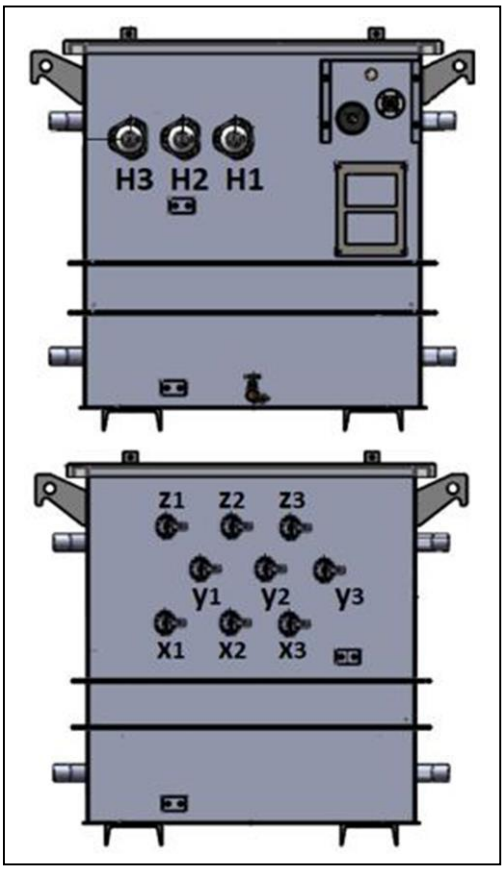


Figure 54: NONAPHASE marking

- The markings in the medium voltage terminals are made with CAPITAL letters and for the low voltage terminals they are made with LOWER CASE letters.

Three-phase transformers have two other very important factors for their connection:

- Connection group
- Hourly index

11.6 Hourly index

It represents the phase angle between the vector diagram of the electromotive forces (voltages) of the primary winding and the secondary winding, when the transformer is in no-load condition.

In other words, it is the phase difference, in degrees, between the primary voltage and the secondary voltage.

The hourly index is so called because the offset is expressed according to the hours of a clock. Every hour, from 12 o'clock, represents a lag of 30º.

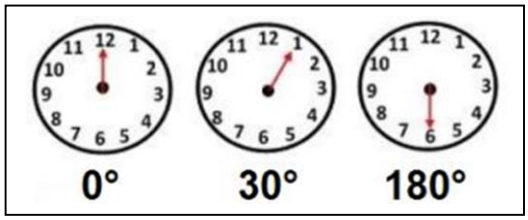


Figure 55: Hourly index examples

11.7 Connection group

It represents the type of connection for each of the windings, normally the primary winding and the secondary winding.

The connection group is represented by a series of letters and a number, as follows:

- The first letter, in CAPITAL LETTER, represents the connection of the highest voltage winding.
- The second letter, in LOWER CASE, represents the connection of the lower voltage winding.
- The number represents the phase difference, in degrees, between the primary voltage and the secondary voltage (1 = 30°).
- If a third letter (N on) is observed in the connection group, it indicates that the star connection (Y oy) has an accessible neutral point.

Example:

Dyn5

D	Indicates the connection of the HIGHEST VOLTAGE winding (Delta or trinagulum).
y	Indicates the connection of the LOWER VOLTAGE winding (Star).
n	Indicates that the star connection (Y or y) has an accessible neutral point.
5	Represents the phase difference, in degrees, between the primary and secondary voltages, in this case 150° (5 * 30°)

Note: Other connection groups:

- Ddo
- Yyn0
- Dyn11
- Ynd5
- Dyn1
- Dz
- Delta-Double delta
- Etc.

12. Review before installation

Before installing the transformer, check the following:

- Remove all traces of dirt and foreign material from the low and medium voltage insulators.
- Clean transformer tank.
- Check that the accessories attached to the transformer are in good condition and properly adjusted.
- Check that there are no insulating liquid leaks.
- Make sure that the transformer does not present blows or damage that could invalidate its proper functioning.
- Review the information on the nameplate and verify that it is in accordance with the requirements (power, voltages, etc.).
- Remove the base and crate (if equipped) from the transformer.
- Verify that the switch is well anchored and in the required position.
- Make sure the low voltage neutral point is properly grounded to the tank.
- Make sure that all the parts and/or accessories to be installed, if any, are complete and in good condition.

13. Tests before installation

The transformers used in the oil sector are of various types as described above, similar to conventional transformers, routine tests are performed with some variations.

In order to ensure the proper functioning of the product and not affect the warranty of the equipment, the following tests must be carried out to validate the installation and energization of the same:

13.1 Transformation Ratio (TTR)

This test is performed to measure the ratio of voltages or turns between two or more windings.

Also, it is a test that allows to identify:

- The connection group.
- Short circuit between turns or layers.
- Failures due to burst or open terminals.
- Damage or misoperation of the commutator.
- Wrong or broken connections.

The transformation ratio of a transformer can be measured by ratio of turns or by ratio of voltages, in the case of phase-shifting transformers, to measure the angular displacement it is necessary to measure the transformation ratio by voltages and in a triphasic way, since by the method of turns it is not possible to obtain this value in degrees of displacement.

When it is possible to carry out the transformation ratio test by turns, the methods with the analogue TTR and the digital TTR for each type of transformer will be exposed.

➢ **Analog or crank TTR**

With this equipment, the ratio of the transformer under test is compared with that of a reference transformer (internal to the equipment) whose ratio is adjustable in small steps.

The transformer under test and the TTR are connected in parallel applying voltage to the MV windings; the LV windings, in parallel, are connected to a sensitive detector which is forced to signal zero (0) by adjusting the transformation ratio of the reference transformer (TTR). The adjusted transformation ratio of the reference transformer (TTR) is then equal to the transformation ratio of the transformer under test.

This procedure must be carried out in all switch positions and in all phases if it is a three-phase transformer.

Figure 56: Analog or crank TTR

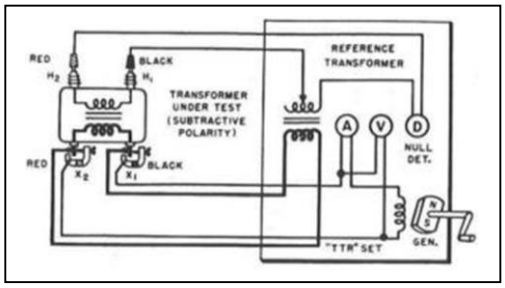


Figure 56-1: TTR connection to the transformer under test

➢ Digital TTR

With this equipment, an adjustable voltage is applied to the MV terminals and the output voltage of the winding corresponding to the LV is measured. The value of the transformation ratio results from the division of these voltages.

The MV and LV terminals of the metering equipment are connected to the MV and LV terminals of the transformer under test according to the marking of the corresponding phases. The equipment must be configured according to the connection group and the voltage to be applied, as standard 8V is used.

Figure 57: Digital TTR

➢ Calculation of the transformation ratio

They are carried out according to the connection group or the polarity of the transformer:

Phases	Connection type	Formula or calculations
1	Ii0 - Ii6	$RT = \frac{\text{Voltage MV}}{\text{Voltage LV}}$
3	Dd - Yy	$RT = \frac{\text{Voltage MV (Coil)}}{\text{Voltage LV (Coil)}}$
3	Dy	$RT = \frac{\text{Voltage MV (L-L)}}{\text{Voltage LV (L-L)} / \sqrt{3}}$
3	Yd	$RT = \frac{\text{Voltage MV (L-L)} / \sqrt{3}}{\text{Voltage LV (L-L)}}$

Figure 58: formulas to calculate the transformation ratio

13.1.1 Autotransformers (PST)

MAGNETRON S.A.S. manufactures two types of phase-shifting autotransformers: Polygonal Delta and Zig-zag. Although they are physically the same, their construction and test method are different.

The polygonal Delta can be tested by both methods, while the Zig-zag can only be tested with the digital TTR, since its construction does not allow single-phase testing.

- **Polygonal Delta with Crank TTR**

Connect the measuring equipment to the transformer as indicated in the table, to check the design turns ratio:

High TTR connection	Low connection TTR
X1 - H1	HH1 - X1
X2 - H2	HH2 - X2
X3 - H3	HH3 - X3

Note: The result obtained must be +/- 1

To check the transformation ratio between the LV coils and the MV coils, connect the measuring equipment to the transformer as indicated in the table:

High TTR connection	Low connection TTR
HH2 - H3	X1 - H1
HH3 - H1	X2 - H2
HH1 - H2	X3 - H3

Note: The result obtained must be +/- 5.5

- **Delta Polygonal and Zig-zag with digital TTR**

This is a verification of the transformation ratio by voltages, in addition, the verification of the displacement between phases is carried out.

Connect the measuring equipment to the transformer as indicated in the table:

Caiman equipment	Transformer terminal
1U	X1
1V	X2
1W	X3
1N	Do not connect
2U	H1
2V	H2
2W	H3
2N	Do not connect

Turn on the measuring equipment, set it up and start the test; when finished, the results should be according to what is related in the following table:

Channel reading	Expected ratio
A (X1 - H1)	Vp/Vs
B (X2 - H2)	Vp/Vs
C (X3 - H3)	Vp/Vs

Similarly, repeat the test to check the displacement between phases XH, X–HH and phases H-HH, the expected displacement is:

Between phases	Offset
X - H	-15°
X - HH	+15°
HH - H	30°

13.1.2 Hexaphase

This type of transformers are made up of a common MV and two independent LVs.

The most used connection groups are Dd0, Dyn1 or Dyn5. Angular displacements are achieved from standard connections.

- **Crank TTR**

The connection of the measuring equipment to the transformer is made depending on the connection group, as follows:

Dd0	
High TTR connection	Low connection TTR
H1 - H2	X1 - X2
H2 - H3	X2 - X3
H3 - H1	X3 - X1
Dyn1	
High TTR connection	Low connection TTR
H1 - H3	X1 - X0
H2 - H1	X2 - X0
H3 - H2	X3 - X0
Dyn5	
High TTR connection	Low connection TTR
H1 - H2	X0 - X1
H2 - H3	X0 - X2
H3 - H1	X0 - X3

- **Digital TTR**

This is a verification of the transformation ratio by voltages, in addition, the verification of the displacement between phases is carried out.

Caiman equipment	Transformer terminal
1U	H1
1V	H2
1W	H3
1N	Do not connect
2U	X1
2V	X2
2W	X3
2N	X0

For Dyn1 and Dyn5 configurations, connect the measurement equipment as illustrated in the following table:

For the Ddo connection, configure the measuring equipment and connect it as indicated in the table:

Dd0	
Terminal TTR	Transformer terminal
1U	H1
1V	H2
1W	H3
1N	Do not connect
2U	X1
2V	X2
2W	X3
2N	Do not connect

13.1.3 Dodecaphasic and nonaphasic

Non-phase (18 pulses) and Twelve-phase (24 pulses) transformers are transformers made up of a common MV and three and four LV respectively.

18-pulse transformers have two connection groups, Dd0 and Dz, 24-pulse transformers are only configured for Dz connection.

These transformers achieve the desired angular displacements from Zig-zag LV connections, which is why the transformation ratio can only be measured using a three-phase digital TTR, since the coils that make up one phase are distributed in two legs different from the core.

To perform the test, set up the measuring equipment and connect it to the transformer as indicated in the table:

Caiman equipment	Transformer terminal
1U	H1
1V	H2
1W	H3
1N	Do not connect
2U	X1
2V	X2
2W	X3
2N	Do not connect

When finished, check the results of the transformation ratio and the angular displacements.

Repeat the procedure for each of the LV.

In transformers with double voltage, the test must be repeated for each primary voltage, specific case Twelve-phase with 2000/415V voltages.

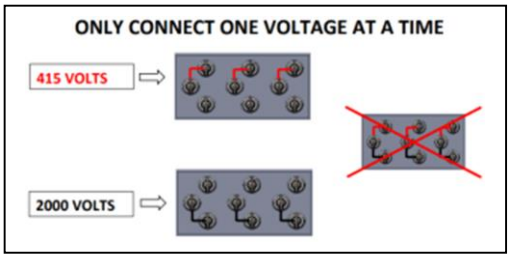


Figure 59: Twelve-phase connection with dual voltage

13.1.4 SUT

The SUT is treated as a conventional transformer, the measurement of the transformation ratio can be carried out in single-phase or three-phase, with delta (D) or star (Y) MV connection.

What makes a SUT different from a conventional transformer is the possibility of adjusting the output

voltage in a wide range, thanks to its coarse adjustment and fine adjustment switches.

The relationship must be guaranteed in each of these positions, in total there are 25 possible combinations (in a typical design); the coarse adjustment switch gives a greater variation of turns with respect to the fine adjustment switch, but a constant variation must be guaranteed between the two, which depends on the voltage ranges requested by the client or corresponds to the design.

- **With crank TTR**

Connect the measuring equipment to the transformer as indicated in the table:

High TTR connection	Low connection TTR
X1 - X2	H1 - H4
X2 - X3	H2 - H5
X3 - X1	H3 - H6

Note: To perform the transformation ratio, set the coarse adjustment tap changer to position 1 and turn the fine adjustment tap changer from position 1 to position 5.

Repeat the above procedure, varying the position of the coarse adjustment switch until reaching position 5, thus obtaining the 25 turns ratio readings.

- **With digital TTR**

Set up and connect the measuring equipment to the transformer as indicated in the table:

Caiman equipment	Transformer terminal
1U	H1
1V	H2
1W	H3
1N	Neutral point if in Y connection. Do not connect if in D
2U	X1
2V	X2
2W	X3
2N	Do not connect

When finished, check the results of the transformation ratio and the angular displacement.

Notes:

- It is standard in SUT type transformers that position 1-1 is the one with the lowest voltage, and position 5-5 the one with the highest voltage, inversely to conventional transformers.
- In the test certificates, MAGNETRON S.A.S. delivers the results for the Ddo connection.
- In ANNEX A, some diagrams of the most used connection groups are illustrated.

13.2 Winding resistance

This test is performed to ensure that the internal connections of the transformer are not loose or open.

13.2.1 Autotransformers (PST)

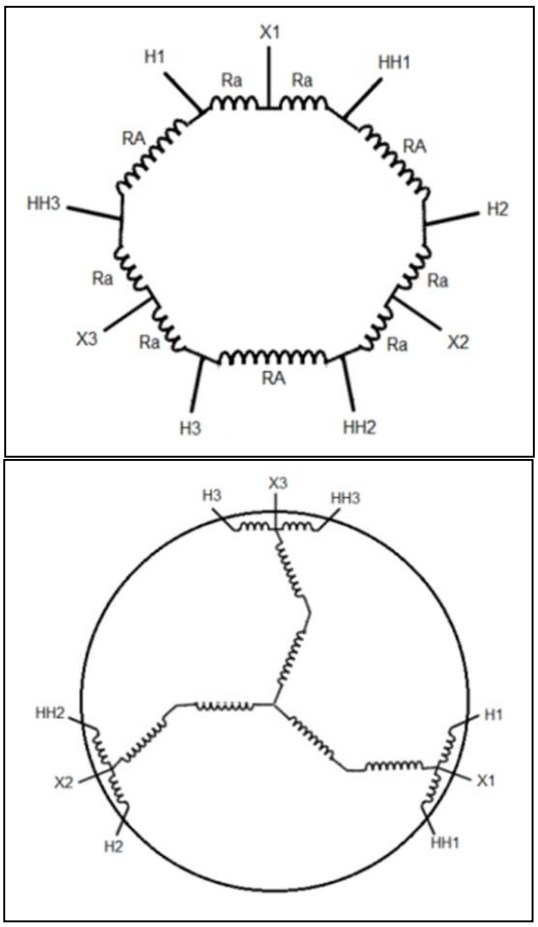


Figure 60: Connection diagrams

This type of transformer requires the measurement of each of the coils that make it up, therefore, the resistance between terminals must be measured according to the following sequence:

- **Polygonal delta**

RA	H1 – HH3	H2 – HH1	H3 – HH2
Ra	X1 – H1	X2 – H2	X3 – H3
Ra	X1 – HH1	X2 – HH2	X3 – HH3

- **Zigzag**

X1 – X2	X2 – X3	X3 – X1
X1 – H1	X2 – H2	X3 – H3
X1 – HH1	X2 – HH2	X3 – HH3

Note: In total, there are nine resistance values that must be taken for each of these transformers.

13.2.2 Hexaphase

It is done in a similar way to a conventional transformer, in this case, the MV resistance and the LV resistance are taken (both for the delta connection and the Y connection).

In total, nine (9) resistance values are taken.

Connect the measuring equipment to the transformer as indicated in the following table:

HV	H1 - H2	H2 - H3	H3 - H1
LV in Delta (D)	Y1 - Y2	Y2 - Y3	Y3 - Y1
LV in Star (Y)	X1 - X2	X2 - X3	X3 - X1

13.2.3 Dodecaphasic and nonaphasic

It is done in a similar way to a conventional transformer, in this case the MV resistance and the

resistance of each one of the LV are taken.

In total, twelve (12) readings are taken for the Nonaphasic and fifteen (15) readings for the Dodecaphasic resistance.

On dual voltage transformers, the test must be repeated for each primary voltage.

Connect the measuring equipment to the transformer as indicated in the following table:

- **Dodecaphasic**

AT	H1 - H2	H2 - H3	H3 - H1
Secondary W	W1 - W2	W2 - W3	W3 - W1
Secondary X	X1 - X2	X2 - X3	X3 - X1
Secondary Y	Y1 - Y2	Y2 - Y3	Y3 - Y1
Secondary Z	Z1 - Z2	Z2 - Z3	Z3 - Z1

- **Nonaphasic**

AT	H1 - H2	H2 - H3	H3 - H1
Secondary X	X1 - X2	X2 - X3	X3 - X1
Secondary Y	Y1 - Y2	Y2 - Y3	Y3 - Y1
Secondary Z	Z1 - Z2	Z2 - Z3	Z3 - Z1

13.2.4 SUT

It is tested as a conventional transformer, it differs in that the measurement must be carried out on the MV windings in delta (D) and star (Y) connection.

In total, nine (9) resistance values are taken.

Connect the measuring equipment as illustrated in the following table:

MT in Delta (D)		
H3-H5 vs H2-H4	H2-H4 vs H1-H6	H1-H6 vs H3-H5
MT in Star (Y)		
H1-H2	H2-H3	H3-H1
BT		
X1-X2	X2-X3	X3-X1

13.2.5 Results analysis

If, when carrying out the test, any of the following cases occurs, the transformer has suffered internal damage:

- When measuring the MV winding, some of the values returned are more or less double what is stated in the test certificate (figure 61).
- When measuring the MV winding, the meter does not record a measurement value.
- When measuring the LV winding, one of the values returned is more or less double that stated in the test certificate or does not register any value (figure 62).

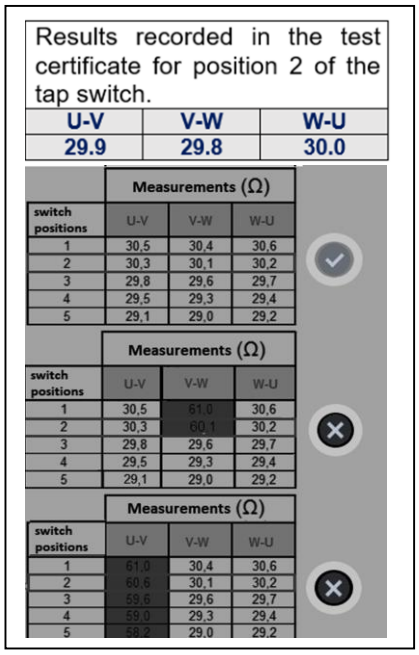


Figure 61: Examples of MV measurements

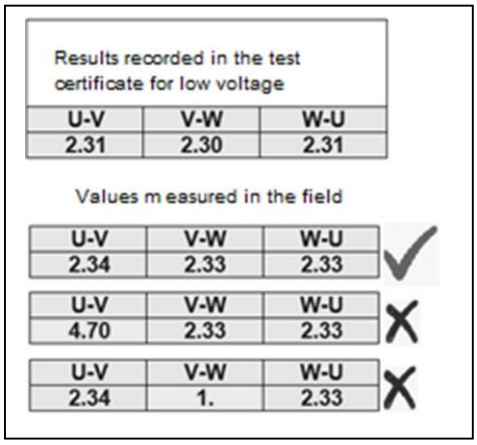


Figure 62: Example of LV measurements

13.3 Insulation resistance

This test is carried out to have a vision of the state of the insulation in terms of contamination by the presence of water, metal particles or foreign elements suspended in the insulating liquid.

- Use a 5 kV megger with a measurement range of 50 MΩ minimum (use the same factory test voltage to minimize drift).
- Test for one (1) minute for each measurement (MV vs LV, MV vs Grd, and LV vs Grd).
- Proceed as follows:

- Short circuit the MV terminals (H1-H2-H3).
- Short circuit all LV terminals (x1-x2-x3, y1-y2-y3, z1-z2-z3, etc.).

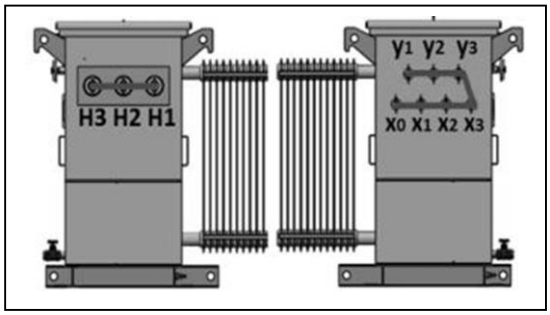


Figure 63: MV and LV terminal short circuit

- To carry out the different measurements (3) the cables are connected as follows:

  - MV-LV: Power cable (+) in MV and black cable (-) in LV, the cable saves anger in a ground terminal.
  - MV-Grd: Power cable (+) in MV and black cable (-) in

Grd, the cable saves anger in LV.

- LV-Grd: Power cable (+) in LV and black cable (-) in Grd, the cable saves anger in MV.

13.3.1 Test voltages

It is recommended to apply the test voltage, taking into account the class of the winding under test:

Class (kV)	Voltage DC (kV)
⩽ 1.2	1
> 1.2	5

13.3.2 Results analysis

This test has no correspondence between the nominal power value, the transformer voltage and the insulation resistance, which is why the minimum values are left to the discretion of the manufacturer.

To verify if the values measured at the installation site are in accordance, keep in mind the following criteria:

- Compare the results obtained against those reported by MAGNETRON S.A.S. in the test certificate, these should be very close to or above what was measured at the factory.
- Take into account the minimum values established by MAGNETRON S.A.S. according to the class of the transformer.

Class (kV)	Minimum resistance (MΩ)
1.2	1,000
15	10,000
34.5	50,000

- Apply James Biddle's empirical formula to calculate the minimum value of insulation resistance:

$$R = \frac{CE}{\sqrt{kVA}}$$

R = Resistance at 20°C of the insulation measured in 1 min

C = Constant for measurements at 20°C
C= 1.6 for transformers in oil
C= 30 for dry transformers
KVA= rated power
E= Rated voltage in volts of the winding under test

13.3.3 Special considerations

- In Autotransformers, only two insulation tests are carried out, bearing in mind that a part of the winding is common to both the primary and the secondary:

  - MV vs. LV
  - LV vs Grd

- In transformers that have a terminal to ground the electrostatic screen, six (6) insulation tests are carried out:

- MV vs. LV
- MV vs Grd
- LV vs Grd
- Screen vs MV
- Screen vs LV
- Screen vs Grd

Caution: If you have any questions or think that water has entered the transformer, contact MAGNETRON S.A.S.

13.4 Insulating liquid tests

The tests on the insulating liquid must be carried out when the transformer:

- It has been stored for a period of more than one (1) year.
- When storage has been carried out outdoors.
- When the insulation resistance results do not meet the criteria.
- When doubts arise due to the possible presence of water (moisture).

The tests on the insulating liquid are carried out to determine the conditions of the same, ONLY with satisfactory results, the transformer can be energized.

The minimum tests required are:

13.4.1 Dielectric strength

This test measures the ability of the insulating liquid to withstand tension without failing.

Dielectric breakdown voltage is used to indicate the presence of contaminants such as water, dirt, or conductive particles in the fluid, one or more of which may be present in significant concentrations when low breakdown voltages are obtained.

13.4.2 Water content

This test method covers the measurement of water present in insulating liquids by coulometric Karl Fischer titration.

The electrical characteristics of an insulating liquid can be negatively affected by excessive water content. A high water content can make a liquid insulating may not be suitable for some electrical applications due to deterioration of properties such as dielectric breakdown voltage.

13.4.3 Color

This test method covers the visual determination of the color of a wide variety of petroleum products, such as lubricating oils, heating oils, diesel fuel oils, and petroleum waxes.

Using a standard light source, a liquid sample is placed in the test container and contrasts against colored glass disks ranging in value from 0.5 to 8.0. When an exact

match is not found and the sample color falls between two standard colors, the larger of the two colors is reported.

13.4.4 Aspect (visual)

The insulating liquid should be optically clear in appearance to allow visual inspection inside the equipment tank.

When the insulating liquid presents a change in its appearance, it is an indication of oxidation, deterioration or contamination, product of the corrosion of metal or other undesirable materials.

13.4.5 Dissolved Gas Analysis (AGD)

The purpose of this analysis is to know exactly the different substances that make up the gases dissolved in the insulating liquid of the transformer.

According to the nature of the dissolved gases, the cause of the abnormality can be determined and corrective measures taken before failure occurs.

When the transformer is subjected to abnormal thermal and electrical stress, due to the degradation of the insulating liquid and insulating papers, certain combustible gases are generated. The type and concentrations of gases generated are important, as the normal aging process produces extremely small amounts of gases, while incipient conditions or declared failures generate large amounts.

Detection of an abnormal condition requires an evaluation of the generated gas concentration and generation trend. The amount of each gas, with respect to the total volume of the sample, indicates the type of failure that is in process.

There are two ways to represent the results of dissolved gases: From the individual concentrations and by the relationships between gases.

The typical gases generated by some incipient faults in power transformers are:

- Hydrogen, Oxygen, Nitrogen, Methane, Carbon Monoxide, Ethane, Carbon Dioxide, Ethylene and Acetylene.

The most common failure mechanisms are:

- Electric arcs in the insulating liquid and in the solid insulation; Corona, Low energy electrical discharges in solid insulation and general overheating or hot spots.

13.4.6 Other tests

Other tests that can be performed on the insulating liquid are listed below:

- Interface tension
- Specific gravity

- Neutralization number
- PCB's content
- Viscosity
- Corrosive sulfur

These tests are should be done when any of the following situations occurs:

- When the results of the minimum required tests present results that are very close to the minimum or maximum allowed.
- By request of MAGNETRON S.A.S.
- By customer request.
- At the request of an external entity.

13.4.7 Sample Quantity Required

To carry out the tests on the insulating liquid, the following are required:

Prueba	Cantidad
Contenido de Agua Rigidez Dieléctrica Color y aspecto Tensión interfacial Gravedad específica Número de neutralización Viscosidad	1000 ml
Factor de Potencia al Aceite a 25°C	1000 ml
Azufre Corrosivo	100 ml
Análisis de gases disueltos	50 ml
Análisis cuantitativo de PCB's	500 ml

13.4.8 Reference values

➢ Mineral oil

Method and test	Reference value
Dielectric strength ASTM D1816	≥ 35kV
Water content ASTM D1533	≤ 35ppm
Color ASTM D1500	≤ 0.5
Aspect ASTM D1524	Clear and bright

➢ Vegetable oil

Method and test	Reference value
Dielectric strength ASTM D1816 1mm gap 2mm gap	 ≥ 20kV ≥ 35kV
Water content ASTM D1533	≤ 200ppm
Color ASTM D1500	≤ 1.0
Aspect ASTM D1524	Clean and clear

Note: Any deviation from the tests and reviews listed in this section must be notified to MAGNETRON S.A.S. in order to receive instructions on how to proceed and not put the transformer at risk. Failure to do so will result in the loss of the warranty.

14. Installation and commissioning

Caution: For Colombia, the installation of the transformer must be done according to the requirements of the technical standards NTC-2050, NTC-3582 and the technical regulation of electrical installations (RETIE).

For other countries, the rules or laws that apply to them must be followed.

The installation of the transformer is not the responsibility of MAGNETRON SAS (unless otherwise specified in the contract), however, as an interested party that the product fulfills its function in the best conditions, the following considerations must be followed:

14.1 Mounting

The installation of the transformer must be carried out in an easily accessible place, where assembly and removal by crane or forklift is guaranteed, with the capacity to lift and transport the transformer.

The transformer must be installed in a place with a sufficient area that allows easy access to carry out inspection, cleaning, maintenance, etc.

If the installation of the transformer is done in closed places (interiors), good ventilation must be guaranteed to avoid abnormal heating.

If the transformer is equipped with fans, it must be ensured that they run in the correct direction,

14.2 Grounding system

- The LV or MV neutral point, the tank, the SPDs and the electrostatic screen must be solidly grounded.

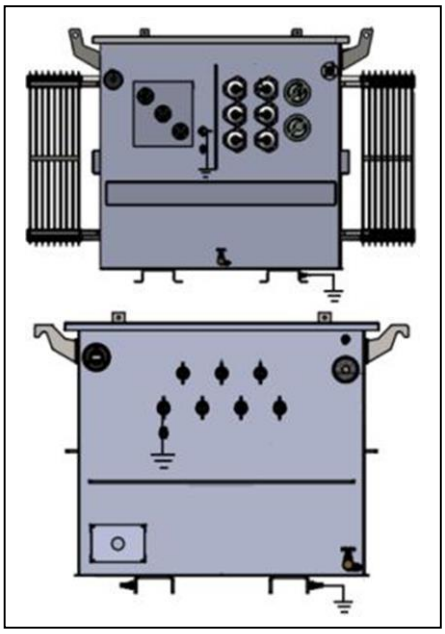


Figure 64: Grounding parts of the transformer

Note: Cabinets and control and protection accessories that require it must also be grounded.

- The objectives of a grounding system are:

  - Guarantee the safety of living beings.
  - Protection of facilities.
  - Electromagnetic compatibility.
  - Allow protection teams to quickly clear faults.

- Serve as a common reference to the electrical system.

➢ Reference values for the grounding system.

Application	Maximum values of grounding resistance (Ω)
Structures and metallic turrets of lines or networks with guard cable	20
High and extra high voltage substations	1
Medium voltage substations	10
Lightning protection	10
Low voltage connection neutral point	25
Networks for electronic or sensitive equipment	10

14.3 Connection sequence

➢ Make all connections to the grounding system.
➢ Make the LV connections.
➢ Make the MV connections.

Caution: The connections cannot be stressed. The medium voltage ones must have a shape and mechanical rigidity that does not allow them to move with the wind or vibrations, in such a way that they come into contact with parts that should not be energized or approaches that produce electric arcs.

14.4 Commissioning

Caution: To energize the product, it must be guaranteed that the tests and revisions listed in number 12 of this manual gave compliant results; otherwise, the energization cannot be carried out and you must contact MAGNETRON S.A.S. personnel to receive instructions.

Also, remember to use the appropriate tools and protections, such as: Pole, dielectric gloves, rubber boots, etc.

➢ Once the transformer is installed, leave it at rest for a minimum of 8 hours for transformers with mineral oil and a minimum of 12 hours for transformers with vegetable oil.

➢ Energize the transformer at no load (no load), keep it like this for about 12 hours.

- Make sure that the transformer does not produce abnormal noises (humming, crackling, flickering, etc.).

- Check the output voltage and check that is balanced and within what is required.

- Gradually install the load and keep checking the output voltage.

- Once all the load is installed, check the operation of the transformer for several hours.

- Keep a written record of the final installation conditions.

- Clean and order the work area.

14.4.1 Energizing transformers with vegetable oil at temperatures below -20°C

Caution: For no reason activate the mobile components (disconnector, switch, magnex, breaker, etc.) before or shortly after their energization.

The C57.12.00-1993 standard considers that initial temperatures below –20 °C are unusual service.

The energization of the transformers immersed in vegetable oil at temperatures below -20°C, can follow the same sequence of the immersed transformers in mineral oil, as long as the following criteria are met:

- Store transformers in such a way that no mechanical movement is required to energize the transformer (disconnect switch in CLOSE position, tap changer anchored in work position, etc.), taking this approach, no mechanical movement should be required. mechanical movement to energize the transformer.

- Do not activate mobile components (disconnector, switch, magnex, breaker, etc.) before or shortly after energizing; in extreme temperature conditions, the insulating liquid becomes more viscous (begins to thicken and, over time, may gel), hindering the mechanical maneuvering of the components and extinguishing electrical arcs more slowly.

- Energize the transformer empty (no load), keep it like this for a minimum of 18 hours.

  Note: Monitor the temperature of the insulating liquid, until it is above room temperature.

- Gradually connect the load.

- After all the load is installed, observe the operation of the transformer for a while.

- To change an internally damaged component (a BAY-O-NET fuse, for example), when the ambient temperature is below -30°C, the transformer must be heated to make the vegetable oil more liquid.

- In transformers with forced ventilation system (fans), during cold start, the insulating liquid of the radiators will heat up more slowly than the insulating liquid of the main tank. For this reason, the fans should not be turned on immediately, they should be turned on when additional cooling is required.

For more information, you can consult the following standards:

- C57.12.93,
- C.57.106
- C.57.12.00.

Or, the guidelines of Cargill, supplier of vegetable oil (FR3):

- G2200S “Transformer Repair Guide”.

- G2300S “Guide for storage, installation, commissioning and maintenance of transformers immersed in FR3 fluid”.

- R2120 “Cold Start Recommendations for Envirotemp FR3”.

14.4.2 Energizing transformers with mineral oil at temperatures below -20°C

The C57.12.00 standard considers initial temperatures below –20°C to be unusual service.

For starting temperatures below –20 °C, energize the transformer and keep it without load for a minimum of 12 hours.

Dielectric fluids can exhibit a drop in dielectric strength at lower temperatures if moisture precipitates. If, at any temperature, the density of the insulating liquid is greater than the density of water, free ice or free water could exist in the system and cause dielectric discontinuity and possible failure.

Any extremely cold transformer should be energized with no load and then gradually increase the load.

Temporarily, localized temperatures may exceed normal values.

These transient conditions are easily tolerated by a properly designed transformer.

At very low ambient temperatures, it will take some time before external

radiators are effective, but at these low temperatures, additional cooling should not be necessary.

15. Transformers with two or more months in storage

If the transformer has been stored for a period equal to or greater than two months, without being energized or since its last energization, the following procedure must be followed:

- Carry out the tests described in this guide, from numeral 13.1 to numeral 13.4.6.
- If and only if the results are satisfactory, proceed as follows:
  - ✓ Energize the transformer without load, for a minimum of 12 hours for mineral oil transformers and a minimum of 18 hours for vegetable oil transformers.
  - ✓ Once the minimum energizing time without load has expired, gradually connect the load, according to the following table:

Connection of the load once the energization time has elapsed (Hours)	% Burden
3	25
6	50
9	75
12	100

- Once all the load is installed, periodically check the operation of the transformer.
- Keep a written record of the final installation conditions.
- Clean and order the work area.

If during the execution of the tests described in this guide, from numeral 13.1 to numeral 13.4.6, you encounter any inconvenience, take into account the recommendations in the table:

Note: If the inconvenience(s) persist(s), do not intervene on the transformer and contact MAGNETRON S.A.S.

Inconvenience presented What to review?	Does not give transformation ratio	It does not give resistance of the windings in MV	Very low insulation resistance	short in insulation resistance	Insulating liquid does not meet the criteria
Check condition of measuring equipment and cables	X	X			
Check correct interlocking of the switch	X	X			
Check disconnector, properly closed	X	X			
Check connection of the TTR to the transformer, according to the connection group,	X				
Check measuring equipment, that it is in the correct range		X			
Cleaning of MV and LV terminals			X		
Test temperature			X		
Correction results by temperature			X		
Check that the neutral point is disconnected from earth				X	
If it has an electrostatic screen, it must not be grounded.				X	
Review sampling process					X
Take a second sample to validate results					X
Take sample when the no-load energization time has elapsed					X

16. Maintenance

Caution: If it is not carried out and evidence of the execution of preventive maintenance, it will cause the loss of the guarantee.

Caution: During the warranty period, report all failures or eventualities to MAGNETRON S.A.S. for no reason does the transformer intervene.

To intervene on the transformer, disconnect the MV and LV voltage sources in order to put it out of service.

Disconnect the MV terminals, short them and connect them to the grounding system.

Disconnect the LV terminals, short them and connect them to the grounding system.

Delimit and mark the work area.

The transformer is an electrical machine designed and manufactured to function 20 years or more under normal conditions of use.

The owner of the transformer is responsible for inspecting, maintaining and keeping it in good condition.

Periodic maintenance and permanent inspection will contribute to the safe and reliable operation of the transformer.

To help you for this purpose, the following must be followed instructions:

16.1 Preventive Maintenance

The following inspections can detect potential operational problems before they become critical, should be done at least once a year:

- External inspection,
- General inspection,
- Tests to the insulating liquid,
- Routine electrical tests,
- Tests to protection devices.

16.1.1 External inspection

Review and record the external conditions of the transformer.

The inspection must include the following points:

- Leaks of insulating liquid.
- Conditions of the grounding system.
- State of the paint, verifying possible oxidation points.
- Internal inspection of control board (if equipped).
- Verification of external electrical connections.
- Verification of tap changer operation.
- Status of control or protection accessories.
- Condition and cleanliness of the tank.
- Condition and cleanliness of the MV and LV insulators.
- Condition and cleanliness of the lightning rods (DPS).

- Condition and cleanliness of the packaging.
- Condition and cleanliness of the overpressure valve.
- Condition of the junction boxes, verifying that they do not show signs of oxidation, presence of water or loose or misaligned terminals.

Eventualities that may arise must be corrected.

16.1.2 General inspection

The inspection includes checking the temperature of the insulating liquid and the windings, the level of the insulating liquid and the internal pressure.

It is important to record the measurements, they serve as a reference for future inspections and help identify potential failures or abnormalities.

16.1.3 Insulating liquid tests

Carry out tests on the insulating liquid every year, the tests that must be carried out are:

- Dielectric strength (ASTM 1816, ASTM D877).
- Power Factor (ASTM D924).
- Specific Gravity (ASTM D1298).
- Color (ASTM D1500)
- interface tension (ASTM D971).
- Neutralization Number (ASTM D974).
- Water content (ASTM D1533).
- Dissolved Gas Analysis (ASTM D3612).

16.1.4 Routine electrical tests

Electrical tests must be performed with the transformer de-energized. They must be carried out every year, when there are doubts about its proper functioning or when an external event occurs.

The tests to be carried out are:

- Transformation relation.
- Winding resistance.
- Insulation resistance.

16.1.5 Tests to control or protection devices

The proper functioning of these devices must be checked every year.

16.2 Corrective maintenance

- For interventions outside the warranty period, contact MAGNETRON S.A.S. or use a specialized transformer workshop.

17. Repair

- The owner of the transformer is responsible for inspecting, maintaining and keeping it in good condition.

- During the warranty period, report all failures or eventualities to MAGNETRON S.A.S. for no reason does the transformer intervene.

- All repairs under warranty must be done by MAGNETRON S.A.S. or an authorized service workshop.

- For repairs outside the warranty period, contact MAGNETRON S.A.S. or use a specialized transformer workshop

18. Problems and possible solutions

Remember to fully comply with the numerals of "Review before installation", "Tests before installation" and "Installation and commissioning" (numerals 12, 13 and 14).

The adjustments of the accessories must be made with a torque wrench and applying the recommended torque in numeral 19 "Adjustment torque".

Accessory adjustments are made only externally, for internal adjustments, contact MAGNETRON S.A.S. or an authorized workshop.

Inconvenience presented / **What to review?**	Expels the canuelas	Blow the fuses	Voltage difference between LV phases	It does not give voltage output in LV	Insulating liquid stain on the VSP	Insulating liquid stain on accessories
Connection of the transformer to the MV line	X			X		
Lightning rod state	X					
Lightning rod characteristics	X					
Energize no load	X	X				
Check condition of fuses		X				
Check that the fuses are correct (amperage)		X				
Correct landing of the transformer (tank)		X	X			
Correct landing of the Pn			X			
Check wiring connection settings			X	X		
Clean and monitor if persists					X	X
Check tightening torque (externally)					X	X
Check input voltage				X		
Check input voltage		X				
Correct anchoring of the commutator				X		
Test the transformer	X			X		

Inconvenience presented / What to review?	Does not give transformation ratio	It does not give resistance of the windings in MV	Very low insulation resistance	short in insulation resistance	Insulating liquid does not meet the criteria
Check condition of measuring equipment and cables	X	X			
Check correct interlocking of the switch	X	X			
Check disconnector, properly closed	X	X			
Check connection of the TTR to the transformer, according to the connection group,	X				
Check measuring equipment, that it is in the correct range		X			
Cleaning of MV and LV terminals			X		
Test temperature			X		
Correction results by temperature			X		
Check that the neutral point is disconnected from earth				X	
If it has an electrostatic screen, it must not be grounded.				X	
Review sampling process					X
Take a second sample to validate results					X
Take sample when the no-load energization time has elapsed					X

19. Tightening torques

Caution: The torques listed correspond to the hardware described in each accessory, consult MAGNETRON S.A.S. whenever an adjustment is required.

Not all the accessories that are part of the transformers are listed.

The different adjustments that are made in the external accessories of the transformer, should be to do following the recommendations of the suppliers regarding torques and sequence of adjustment. The most relevant are listed below:

19.1 Screws in general

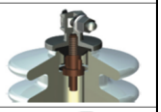
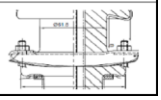
Torque (lbf * ft)						
Iron				Stainless steel		
Diameter	Grade 2	Grade 5	Grade 8	Diameter	A304	A316
1/4	5,5	8	12	1/4	6	7
5/16	11	17	25	5/16	11	12
3/8	20	31	44	3/8	20	21
7/16	32	49	70	7/16	31	33
1/2	49	75	107	1/2	43	45
9/16	70	109	154	9/16	56	59
5/8	97	150	212	5/8	92	96
3/4	173	266	376	3/4	127	131
7/8	166	429	606	7/8	194	202
1	250	644	909	1	286	299
1-1/8	354	794	1287	1-1/8	413	432
1-1/4	500	1120	1875	1-1/4	523	546
1-3/8	655	1469	2382	1-1/2	888	930
1-1/2	870	1950	3161			

Note: The tightening torques in the table correspond only to the screws, wh used to hold accessories (porcelain, polymers, etc.) the tightening torque is defined by the material.

19.2 Lid-Tank screws adjustment

Screws		
Torque (lbf * ft)		
Diameter	80%	100%
5/16"	14	18
7/16"	32	40

19.3 MV and LV bushings

Product	lbf * ft	Image
MT spider nut	70	
BT spider nut	29	
BT aluminum nut	35	
Stud adjustment to connect MT	18	
Anchor adjustment 7 mm to 11.9 mm	13	
Anchor adjustment 12 mm to 16 mm	15	
Anchor adjustment 19 mm to 32 mm	19	
Bolt adjustment for external clamping flanges	12	

19.4 Tap changer

Accessory	lbf . ft	Image
SWITCH nut	8 to 9	
Linear commutator nut	11	 

19.5 Overpressure valves

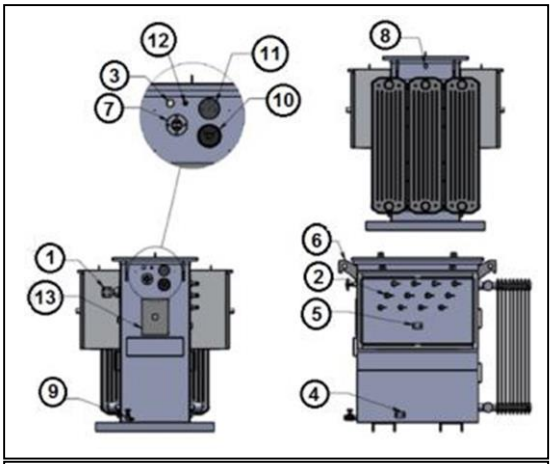
Overpressure valve	Tightening torque	Image
1/4"	20 to 25	
1/2"	54	
3/4"	83	
1-1/4"	121	

19.6 Two (2) Contact Oil Thermometer

Detail	Description	TORQUE (lb-ft)
A	3/16" INOX thread fitting	4,6

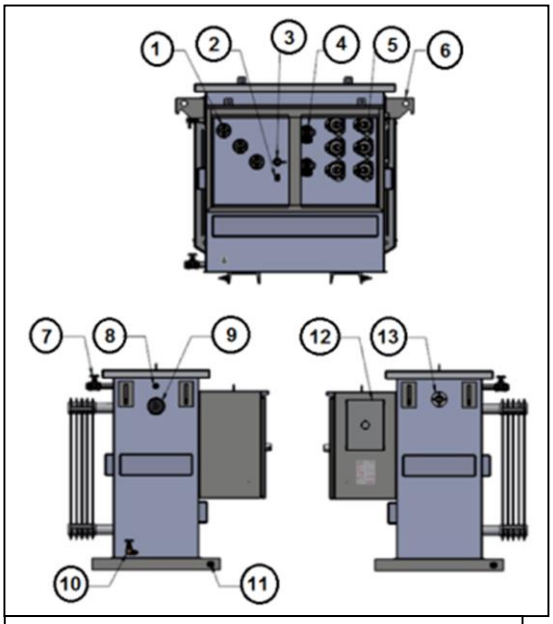
20. Transformer parts

20.1 Autotransformer



Item	Description
1	Primary connection terminal
2	Secondary connection terminal
3	Overpressure valve
4	Tank grounding
5	Pn grounding
6	Transformer lifting devices
7	Insulating liquid level
8	Filling valve or nipple
9	Drain valve
10	Insulating liquid thermometer
11	Manovacuometer
12	Nitrogen filling
13	Nameplate

20.2 SUT



Item	Description
1	Primary connection terminal
2	Grounding electrostatic screen
3	Electrostatic screen isolator
4	Switch
5	Secondary connection terminal
6	Lifting devices transformer
7	Filling valve or nipple
8	Overpressure valve
9	Insulating liquid thermometer
10	Drain valve
11	Tank landing
12	Nameplate
13	Insulating liquid level

21. Environment

MAGNETRON S.A.S. is a company committed to the environment, for this reason, our transformers meet all the requirements related to the subject.

MAGNETRON S.A.S. has identified potential risks that may cause harmful environmental effects on the environment.

Likewise, MAGNETRON S.A.S. provides its clients with a series of environmental advice, in order to prevent and minimize contamination throughout the life cycle of the transformer.

The environmental councils are consigned in the environmental management plan, made up of 5 environmental management programs.

If you want to know more about environmental programs, contact MAGNETRON S.A.S.

The final receiver of the transformer must comply with current legislation and that applies to it.

In the event of leakage of the insulating liquid, must be collected in a container, avoid it falling on the ground.

- If insulating liquid has been spilled on the floor, clean it up with an absorbent material (example: sawdust).
- The insulating liquid that has been collected and the media used for cleaning must be treated as toxic and hazardous waste.
- Waste should not be mixed.

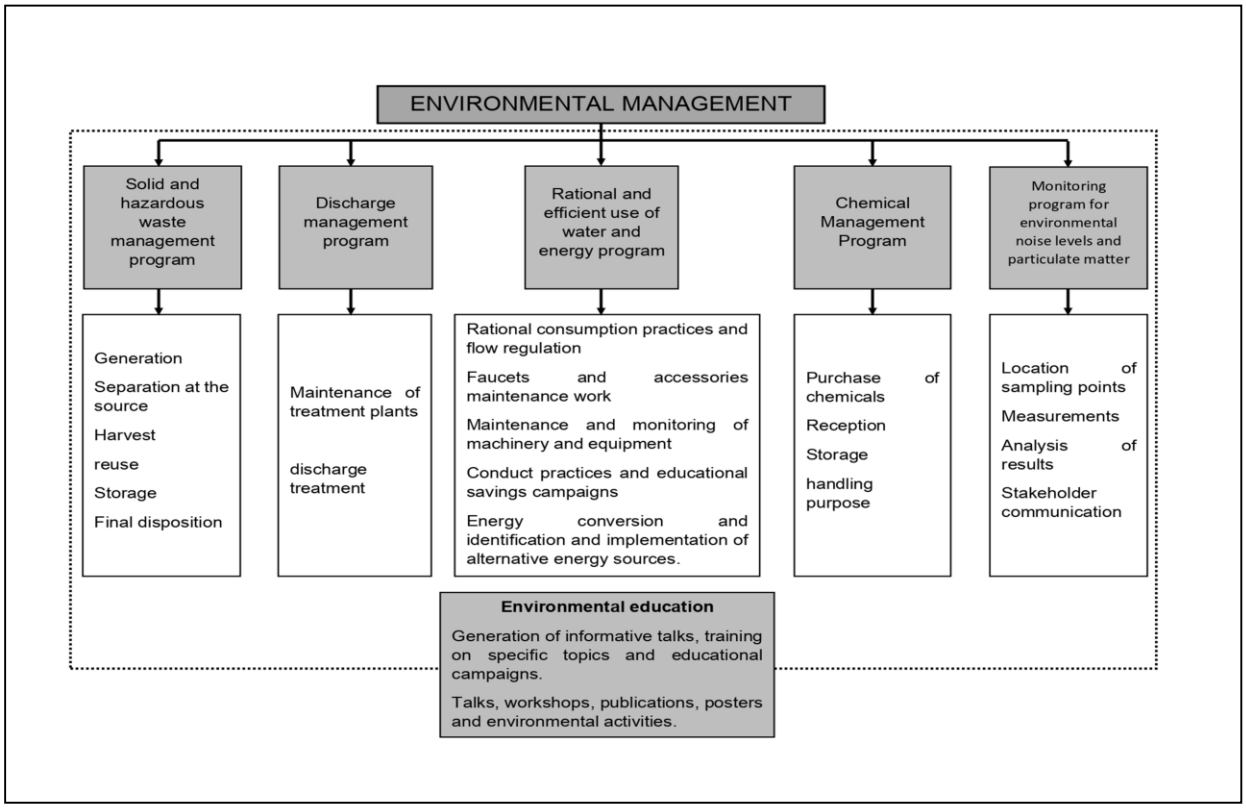
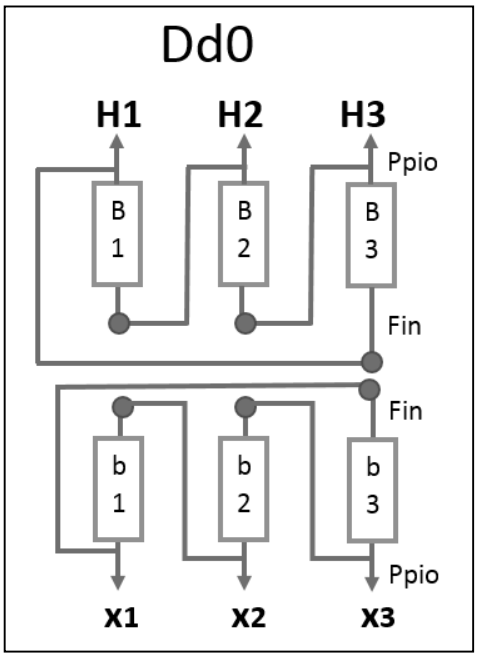


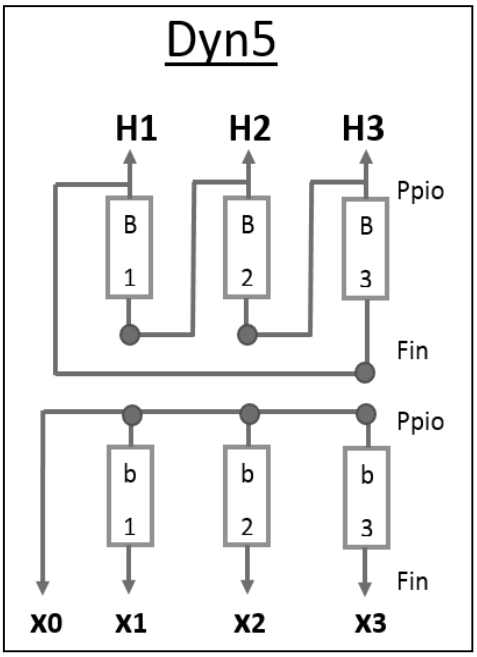
Figure 65: MAGNETRON S.A.S. Environmental Management Plan

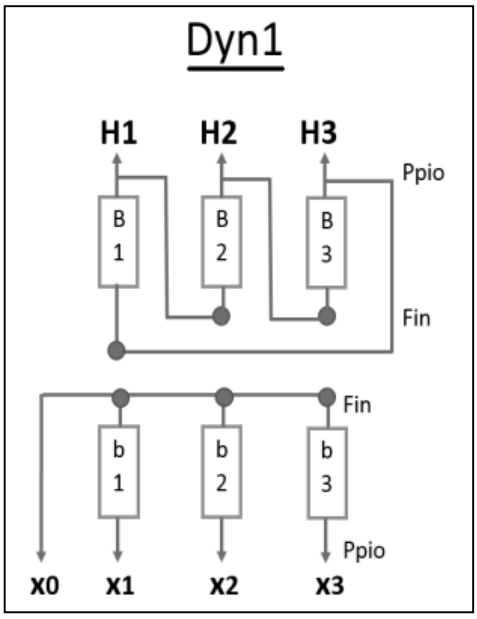
22. Warranty Terms and Conditions

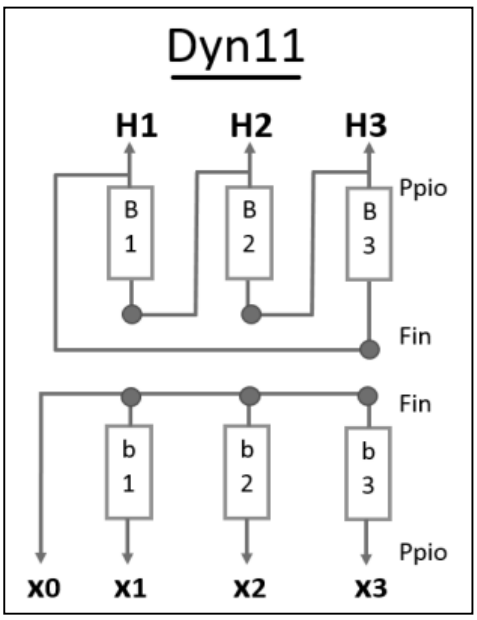
Refer to the guarantee certificate that is delivered with each product; behind it, there are the instructions that must be followed to make the guarantee effective and the conditions that invalidate it.

23. Annex A "Connection coils with ANSI markings"









24. Contact Us

For more information or to provide technical support, contact us through the following means:

	servicioexterno.magnetron.com.co
	customerservice.magnetron.com.co
	(57) 3187117456 (57) 3157100 extension 101