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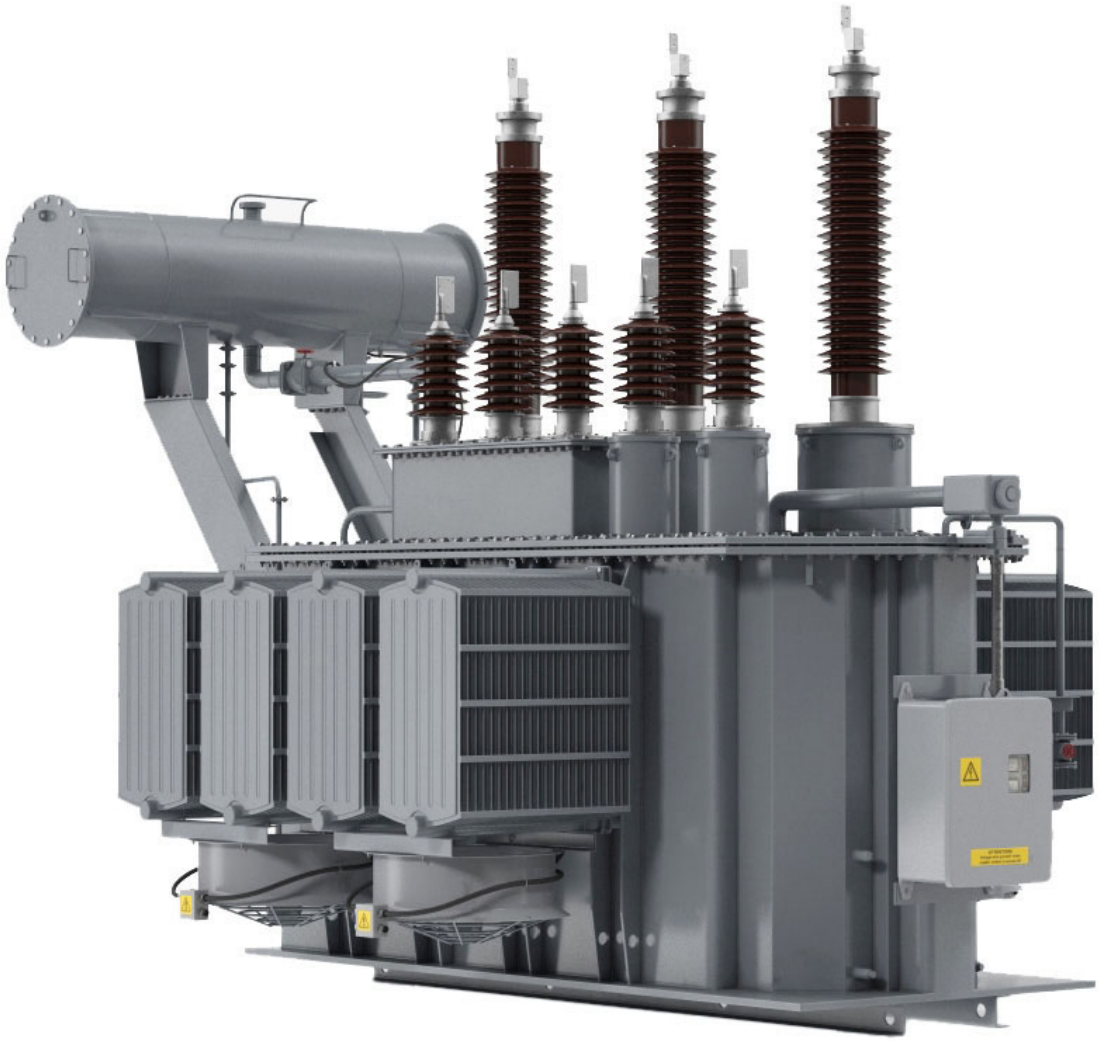

SUBSTATION TRANSFORMER MANUAL

Meta-Power Solutions ®

Product information

Introduction

This instruction manual will help guide competent technicians in installing, operating, and maintaining threephase Substation Transformers.

This manual was made after anticipating most normal installation, operation, and servicing problems. However, the instructions do not cover all possible scenarios where equipment or application conditions may vary. In such cases, additional information can be obtained by contacting a factory representative at:

Meta Power Solutions (MPS)
500 S Australian Ave Suite 600, West Palm Beach, FL 33401

Read this manual first!

It is important that a technician reads this manual, understands its contents, and follows all locally approved practices and safety procedures before connecting or operating a three-phase substation transformer.

Additional information

This instruction manual cannot cover every detail or variation in the equipment, process, or procedure described, nor can it provide directions for meeting all possible contingencies during the equipment installation, operation, or maintenance. Contact your Meta Power Solutions representative for additional information if the need arises.

Safety information

The instructions in this manual are not meant to be used as substitutes for proper training and experience in safely operating the described equipment. Only “competent technicians” should be allowed to install, operate, and service the equipment.

A competent technician should have the following qualifications:

- They are thoroughly familiar with the instructions given here.
- They are properly trained in industry-accepted low-voltage and high-voltage safe operating procedures and practices.
- They are adequately trained and fully authorized to energize, de-energize, ground, and clear power distribution equipment.
- They are properly trained in the care and use of protective equipment such as rubber gloves, face shields, safety glasses, hard hats, clamp-stick, arc flash clothing, hot-stick, etc.

Safety instructions

The following statements are general warning and caution statements that apply to Overhead Distribution Transformers. For specific tasks and procedures, additional warning and caution statements are provided throughout this manual.

Receiving

Once it is received, the transformer unit should immediately be inspected for signs of mishandling and damage that might have occurred during the shipment. Notify your MPS representative in case any evidence of a defect or damage is identified, and file your claims for damage with the delivering carrier.

Parts and attachments of the transformer that became loose or damaged during the shipment should be tightened, repaired, or replaced before the transformer is moved.

CAUTION:

First, check the transformer nameplate to find the unit’s total weight. Then, check the lifting capacity of all available hoisting and lifting equipment, and only use the cranes and forklifts if their load capacity exceeds the transformer weight. Use only the lifting lugs to lift units from above; do not use the bushings and other accessories in place of handles. Do not use damaged hooks, slings, or cables. Take care when lifting the unit and removing it from the truck so it does not get damaged.

WARNING:

Hazardous voltage. Contact with hazardous voltage can cause severe injuries and even death. Personnel working around low-voltage and high-voltage lines and equipment should follow all locally approved safety procedures and practices.

WARNING:

Carefully read and understand the contents of this manual before installing, testing, operating, or maintaining a Substation Transformer unit. Improper handling, operating, or maintenance of the equipment can cause equipment damage, severe injuries to personnel, and even death.

WARNING:

This equipment is not intended to protect human life but to distribute power. Locally approved practices and safety procedures should be followed while installing or operating this equipment. Non-compliance with these safety procedures can result in equipment damage, severe injuries to personnel, and even death.

WARNING:

The selection of power distribution and transmission equipment should match its intended application, with installation and servicing conducted by trained and competent personnel who understand safety protocols. These instructions are intended for such personnel and should not replace proper safety training and experience. Failure to correctly select, install, or maintain power distribution and transmission equipment can lead to severe personal injury, equipment damage, and even death.

Moving the Transformer

Moving Transformer Shipped on Pallets

If the transformer and other equipment are shipped on pallets, they may be moved using cranes, hoists, and forklift trucks of proper capacity.

WARNING:

Non-palletized transformers and other equipment should not be lifted with forklift trucks because doing so could result in personal injury and equipment damage.

Lifting the Transformer by Crane or Hoist

Lifting lugs should be used to unload the transformer. These are found near the top of the transformer tank. The pull angles for the lifting cable should not exceed 30° from the vertical plane. If they exceed this angle, the lifting cables should be held apart with the help of spreaders to avoid any bending in the lifting hooks or the tank itself. Oblong hooks, links, and other similar lifting hardware should not be used under the lifting lugs because they could compromise the load rating of the lugs. The transformer should not be lifted by looping a chain or cable around the unit or lifting lugs.

WARNING:

Use all the provided lifting pads and lifting lugs to lift the transformer. Using transformer apparatus like cooling fans and radiators for lifting could result in personal injury and equipment damage.

Skidding/Rolling Transformers

The design of MPS transformers allows them to be skidded or rolled into place without needing overhead lifting devices like cranes and hoists. If the unit must be rolled into place, then sufficiently thick and strong rollers must be used to support the weight of the transformer unit. When using roller bars, verify the bars extend beyond the walls on flat-bottomed tanks. Multiple rollers may be used to ensure the unit's weight is distributed uniformly throughout the moving process. The path to the installation place should be level and free of debris and obstructions.

Storage

MPS ensures that all its units are thoroughly dried at the factory and filled with dry air or nitrogen or the correct oil level before shipment. It is important to store transformers with oil in place because the oil can prevent possible absorption of moisture and other contaminants. Transformers should be stored in an area with low humidity and stable ambient temperatures. If possible, transformers should always be stored in their permanent location and upon a foundation that is specifically built for it. If no such permanent locations or foundations exist, a transformer should be stored on a level foundation in the correct upright position; however, it should be ensured before storage that the foundation can withstand the weight of the transformer without deformation.

CAUTION:

- Transformers should never be stored on rollers.
- A transformer should never be stored solely under the jacking steps, on jacks, or on temporary blocking.
- Transformers should not be stored close to standing water or in areas with high salt levels, moisture content, and corrosive gases in the air, if possible.

Storage for More Than 90 Days

MPS ships all of its transformers with a 2-psi dry-nitrogen blanket. However, the blanket should be maintained by adding dry nitrogen bottles when units are stored for long durations. These bottles may be added to the transformer tank through a regulator.

Transformer units may have anticondensation heaters installed in their control cabinets. If present, ensure that they are energized and that they work properly. Units with Air Terminal Chambers, control cabinets, or any other enclosed air-filled spaces should utilize heaters, either permanent or temporary, to prevent condensation from occurring.

Installation

Installation Location

A transformer unit should always be installed on top of a level concrete pad with sufficient strength to support the unit's weight. The selected location for the installation of the transformer, whether outdoor or indoor, should provide adequate ventilation, accessibility, and ease of inspection. Areas with corrosive chemicals should not be selected as possible installation sites. No tools, debris, or obstructions should be left near (at least 24 inches) the unit. These recommendations are given by the manufacturer for operation purposes only; local and national codes should be followed for more detailed guidelines.

MPS substation transformers are designed to operate at altitudes of up to 3300 feet with an average ambient surrounding temperature of 30°C and a maximum ambient temperature of 40°C unless specified otherwise. Contact your factory representative before installing and operating a standard transformer at higher altitudes or ambient temperatures.

Transformers must be provided with adequate ventilation. For indoor systems, the room air inlets should be located at floor level, while the outlets should be located at the highest possible level permitted by the room. The size and number of air inlets and outlets are determined by the rating of the transformer. Generally, approximately 20 ft2 of air inlet and outlet area must be provided for every 1000 kVA of transformer capacity. Adjustable ventilation systems should be permanently locked in the open position to prevent the transformer unit from overheating during operation.

Connections

All conductors must be fastened securely in place and appropriately supported, with allowance for contraction and expansion. The connections should be made without placing any undue stress on the bushing terminals. Ensure that tap connections are properly made for the required operating voltages. Tap connections must be changed ONLY after completely "DE-ENERGIZING" the transformer unit and after verifying that no voltage is present at the unit terminals.

WARNING:

Ensure the transformer unit is properly de-energized before making or changing its connections. Make transformer connections only after grounding all circuits so that there is no stored charge inside the unit. Failure to observe these precautions can expose workers to high-voltage shocks when making connections, resulting in equipment damage, severe burns, personal injuries, or even death.

WARNING:

Never make a connection not authorized by the transformer schematic and nameplate. Improper connections on a transformer can lead to severe personal injury, equipment damage, and even death.

Transformer units equipped with an internal terminal board are generally shipped with a connected higher voltage unless specified otherwise by the customer.

An effective and secure low-resistance ground is essential for protecting the transformer unit. Every unit must be permanently grounded. To do so, a heavy ground cable must be connected to the transformer ground pad, typically located at the bottom of the tank. For transformers designed to operate in solidly grounded neutral systems, the neutral connection should be permanently and solidly grounded with minimum resistance.

WARNING:

All transformers should be properly grounded, as improper grounding may result in severe personal injury and equipment damage. It is strongly recommended that all transformer installations should be equipped with lightning arresters. Properly rated arresters should be located as close to the transformer terminations as possible. If alarm controls or contacts are supplied along with transformer accessories, a connection box might be provided to enable the termination of the customer's conduits and cables.

Final Inspection

All conductors must be fastened securely in place and appropriately supported, with allowance for contraction and expansion. The connections should be made without placing any undue stress on the bushing terminals. Ensure that tap connections are properly made for the required operating voltages. Tap connections must be changed ONLY after completely "DE-ENERGIZING" the transformer unit and after verifying that no voltage is present at the unit terminals.

WARNING:

Ensure the alarm, interlocks, or control circuits are not tampered with. Tampering with these accessories can produce unsafe conditions for operators, resulting in personal injuries and equipment damage.

Electrical inspections are performed to:

1. Ensure that there is continuity in all transformer windings.

2. Ensure that all connections are made as secure and tight as possible and that all the accessory contact circuits work properly.

3. Ensure that all external connections are made correctly and properly. For example, the phasing of connections to erminal bushings is checked as part of electrical inspections.

4. Ensure the correct transformer ratio exists for units furnished with internal terminal boards.

5. Check whether the current transformer circuits, if supplied, have their secondary windings shorted or connected through a load.

6. Confirm the Tap changer position and check whether or no t it meets the required conditions for operations.

7. Ensure that the windings designed to be operated without grounding are not grounded by mistake. A 1000-V megger test may be performed to verify the grounding condition of such windings.

8. Check the dielectric strength of the insulating fluid within the transformer unit. The dielectric strength should be 30 kV minimum for new insulating fluids.

9. (Refer to the section "Testing Insulating Liquid" in this manual for further details.) i. Confirm that the ground and neutral connections have been made properly.

Internal inspections are not routinely made and should be performed only if possible internal damage is suspected. Before performing an internal inspection, make sure that:

1. There is no moisture evidence in the transformer unit's surrounding area.

2. All available bolted connections are tightly secured.

3. No parts have been shifted, and there have been no signs of damage or tampering on the unit.

The external inspections are performed to:

1. Confirm that the mechanical pressure relief device is reset.

2. Verify that the correct liquid level is evident.

3. Verify the operations of the accessories.

4. Verify that all scratches have been properly repaired.

5. Ensure that the bushings are clean.

6. Check whether or not the transformer unit holds positive pressure.

7. Check for any tools or objects that may have been left near the transformer.

8. Ensure that the manhole covers are tightly bolted.

9. Ensure that all protective covers are tightly bolted and closed.

CAUTION:

Before opening a liquid-filled transformer, ensure that the liquid inside the transformer has a higher temperature than the air in the surrounding environment. Otherwise, internal moisture condensation might occur, which can lead to the failure of the transformer.

CAUTION:

Bleed the internal pressure of a transformer to zero before breaking the seal of any manhole, handhole, or bushing hole. Do not break the seals in the presence of rain, snow, or fog or if there is evidence of condensation on the tank of the transformer unit. Even small amounts of moisture inside the transformer tank can reduce the dielectric strength of the cooling liquid to very dangerous levels. This reduced liquid strength can cause serious equipment damage to the transformer unit.

CAUTION:

Only authorized personnel should be allowed to go on top of a transformer. Every precaution must be taken to ensure no objects are accidentally dropped into the transformer. While working above a transformer, workers should not have any unnecessary items in their pockets, such as pencils, pens, coins, etc. Their clothing should also be checked to ensure no loose metal buttons, badges, buckles, or any similar items in their attire. Wristwatches should also be removed from their hands. When such objects get dropped into the transformer tank, they can cause severe equipment damage and malfunctions.

Field Testing

The information below is meant to be used as a guideline for transformer field testing. For more details, please refer to IEE/ANSI C57.12.90-2006 and ANSI/ NETA ATS-2009.

Ratio Test

The transformer turn ratio measures the relationship between its two windings. It is obtained by taking the ratio of the number of high-voltage winding turns to the number of lowvoltage winding turns.

NOTE:

The ratio test can also test transformer phase polarity, sequence, and relation.

Winding Resistance

Measuring the Winding resistance is a fundamentally important task because it allows us to calculate the 2R component of conductor losses. These values are needed to calculate the total temperature of a winding through the temperature rise test.

Insulation Power Factor Test

The insulation power factor is a parameter used to judge the quality of the transformer insulation. It is obtained by taking the ratio between the power (watts) dissipated within the insulation and the effective power (volt-amperes). Effective power is the product of the effective voltage and current values obtained by testing the transformer response with sinusoidal voltages and controlled conditions.

Insulation Resistance Test

The Insulation resistance test is conducted to find the total insulation resistance between individual windings and between individual windings and ground. Its value may be measured in units of mega-ohm or calculated from measured values of applied voltage and leakage current.

Bushing Power Factoring

Bushings should only be inserted into a transformer after being power factored. If the required Power Factor set is not available during the transformer assembly process, then at least a capacitance bridge must be used to measure the tap capacitance values of the bushings. A capacitance test can highlight any serious internal problems in the bushing and indicate whether or not a power factor test must be performed before installation.

Sweep Frequency Response Analysis

The Sweep frequency response analysis (SFRA) is a transformer test used to evaluate the frequency response of certain passive electrical elements within the transformer assembly, including the transformer core, windings, and clamping structures. The SFRA test results in a transfer function that produces a fingerprint related to the mechanical geometry of the transformer.

SFRA is simple to perform and requires the transformer to have similar conditions as the standard Doble Power Factor test. The transformer must also have good connections and grounding.

The fingerprint obtained from an SFRA test features many resonances in the 20 Hz – 20 MHz range. Each resonance is strongly related to the internal capacitances and inductances of the transformer, which are, in turn, related to the internal geometry of the transformer. Test results are compared to previous SFRA and phase-to-phase short circuit tests to check for variations. Any observed variation must be investigated as it implies some distortion or movement within the transformer elements.

Transformer Core Ground Test

The Transformer Core Ground (TCG) Test is an offline lowvoltage test that helps to check the insulation between the transformer core and its tank by detecting the presence of unintentional core grounds. According to IEEE Std 57.12.90- 1999, clause: 10.11 “Insulation resistance tests”, the TCG test must be considered a “Routine” Test for Class II transformers and as an “Other” test for Class I transformers.

Usually, a TCG test is performed on a transformer when it is moved from one location to another, when it’s first installed at the site, and when the Dissolve Gas Analysis (DGA) test indicates a problem. The following table shows the acceptable TCG test result values and the corresponding recommendations and steps.

Core Ground Resistance (in MΩ)	Recommendations
R > 200	Acceptable.
100 ≤ R ≤ 200	Probable Core Ground, Further investigation is advised.
10 < R < 100	Definite Additional Core Ground. Timely intervention is necessary.
0 ≤ R ≤ 10	Severe Core-Ground issue. Urgent intervention is necessary.

Single Phase Excitation

The single-phase excitation test is performed to verify the inner design and performance of the transformer and to check the transformer for signs of failure in its winding insulation system and signs of displacements within its core due to longdistance transport.

The effective reluctance of the transformer magnetic circuit can change due to defects and problems in the transformer's magnetic core structure, tap changer, windings, block-toblock insulation, and turn-to-turn insulation. The reluctance change can affect the current requirements for establishing the required flux in the core, which can negatively affect transformer operations.

Low-voltage Single-Phase Excitation can be used for power transformers to deal with these problems. Single-phase excitation can also be used as an auxiliary judgment method to indicate the condition of a transformer.

Accessories

Accessories are optional, and additional equipment may be installed on a three-phase substation transformer. They include a variety of switches, pressure relief devices, gauges, etc. Accessories are mostly installed at the factory before shipment of the transformer and do not require fieldwork to become operable. Always install attachments and accessories by following the relevant manufacturer's instructions and ensure that all connectors are rated correctly.

Liquid Level Gauge

Liquid level indicators help transformer operators and workers systematically inspect the transformer, even in loaded conditions. This device consists of three components:

- A floating arm that moves vertically with the oil level inside the tank.
- An indicating pointer outside the tank that is separated from the float arm physically due to the liquid-tight construction of the tank,
- A magnetic coupling mechanism between the above components allows the pointer to move in response to the position of the float arm, even with the liquid-tight separation between them.

Under normal operating conditions, the pointer should indicate the liquid level between the LO/MIN and HI/MAX level markings. The liquid level gauge may use one or two Single-Pole Double-Throw (SPDT) alarm contacts to give a remote indication when the liquid levels become very low. More information on the wiring and contact ratings can be found on the schematics that are furnished with the transformer.

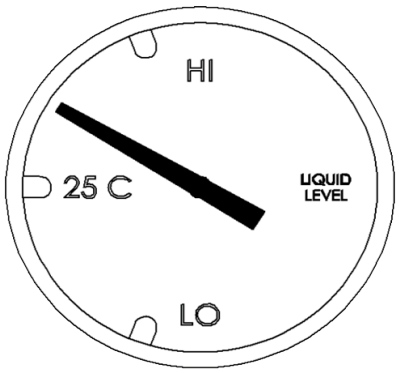

Figure: Liquid Level Gauge

Liquid Temperature Gauge

Liquid temperature gauges help indicate the top liquid temperature inside the tank in units of degrees Celsius. The device has a temperature-sensitive element that can be mounted in a leakproof well. The well allows the transformer operators to remove the thermometer without lowering the transformer oil level. An additional red pointer in the device is used to show the highest temperature that was recorded since the last reset. The maximum indicator can be reset by turning the knob in the dial's center. The thermometer may use two Single-Pole-Double-Throw (SPDT) contacts to energize a high-temperature alarm or a fan circuit. More information on the wiring and contact ratings can be found on the schematics that are furnished with the transformer.

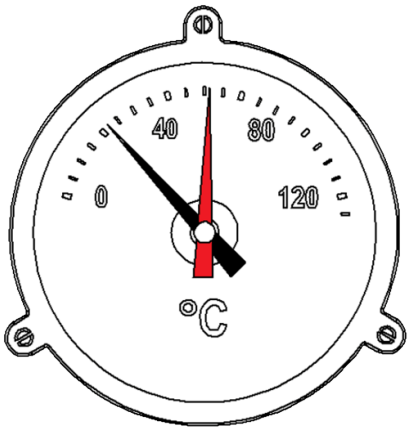

Figure: Liquid Temperature Gauge

Pressure-vacuum gauge

Pressure vacuum gauges help indicate whether the gas spacein the tank is under negative or positive pressure. The tankpressure can vary with the transformer temperature andloading conditions. For example, the pressure may benegative for a de-energized transformer and a transformeroperating under light loading and low ambient temperatureconditions.

NOTE:

The transformer unit should be checked for possible leaks inits seal if the indicator stays at zero, even when the loadingconditions are varied.

Due to changes in ambient temperature and loading, thetransformer may operate in the vacuum range. This is not acause for concern, provided that the pressure vacuum gaugedoes not indicate a leak by remaining on zero for any lengthof time. Generally, a transformer can operate safely inpressures ranging from -2 psig to +6 psig. The transformermay use pressure vacuum switches and two Single PoleDouble Throw (SPDT) contacts to generate an alarm in caseof excess negative or positive pressures inside the tank. Moreinformation on the wiring and contact ratings can be found onthe schematics that are furnished with the transformer.

For units with an automatic nitrogen oil preservation system,the transformer is furnished with a regulator that canautomatically regulate the pressure inside the transformertank to maintain a positive pressure.

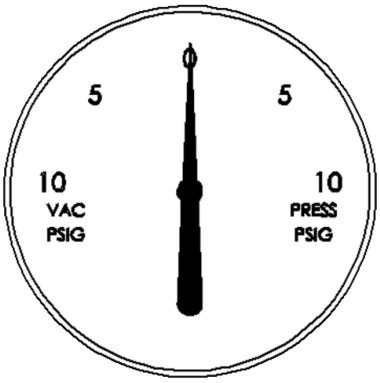

Figure: Pressure Vacuum Gauge

Pressure Relief Device

All substation transformer units come equipped withmechanical pressure relief valves (PRV) and/or covermountedpressure relief devices (PRD) for improvedprotection against pressure accumulation inside thetransformer tank. The PRD devices comprise a spring-loaded,self-resetting diaphragm and a mechanical operationindicator. If the pressure inside the tank increases beyond theset value of the PRD, then the diaphragm gets lifted by thegas pressure, allowing the gas to escape quickly. The gasrelease resets the PRD diaphragm back to its original positionand reseals the transformer. The mechanical indicatorprotrudes vertically and must be manually reset forsubsequent operations.

Winding Temperature Gauge

Larger transformers are furnished with a winding temperaturegauge. The gauge consists of a temperature-sensitive stemmounted in a leakproof well. This construction allowsworkers to remove the instrument and stem without affectingthe liquid level inside the transformer. The well can be heatedby the surrounding liquid and a heater element. This heaterelement is energized using a current transformer mountedinside the transformer tank. The heater element is used tosimulate the hot-spot winding temperature gradient. Thecombined effect of the two temperatures is displayed on thegauge. An additional red pointer in the device is used to showthe highest temperature that was recorded since the last reset.The maximum indicator can be reset by pressing thepushbutton at the bottom of the dial bezel.

The winding temperature gauge is calibrated at the factory toindicate the hottest spot on the transformer windings and usesthree separate Single Pole Double Throw (SPDT) switchesfor alarm and fan control circuits. More information on thewiring and contact ratings can be found on the schematics thatare furnished with the transformer. Additionally, the contactsettings are factory-set to operate at certain temperatures.Refer to the connection diagrams furnished with thetransformer for more information on these contact settingsand the applicable temperature ratings.

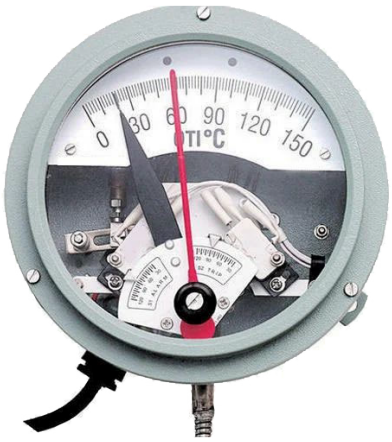

Figure: Winding Temperature Gauge

Transformer Cooling Fans

Fans are furnished with substation transformers whenadditional ratings above the self-cooled level are specified.The fan control circuit consists of a contact on either thewinding temperature gauge (when furnished) or the liquidtemperature gauge and a “Manual-Auto” control switch. If thecontrol switch is turned to the “Manual” position, the fans areoperated continuously. In the “Auto” position, the contactinformation on the temperature gauges triggers the fans onand off depending on the transformer winding temperatures.More information on the transformer cooling fan temperatureand contact settings can be found on the schematics that arefurnished with the transformer.

WARNING:

Fans are furnished with fan guards that meet OSHArequirements to protect the transformer fan equipment andany personnel working near an energized transformer. Do notremove the fan guards or use long objects to probe into thefan. Doing either can result in severe personal injuries,equipment damage, or even death.

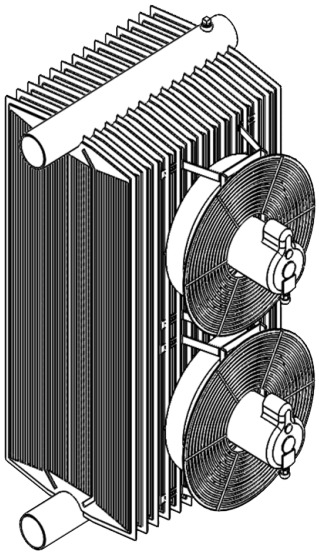

Figure: Transformer Cooling Fans

High Voltage Bushings

High-voltage leads are normally brought through the tankcover or side wall using a porcelain or cycloaliphatic epoxy bushing. Only flexible connections should be made to thebushing terminal to avoid excessive mechanical loading. Abushing is used for making connections. It should never beused as a support or structural member to other currentcarryingcomponents of the transformer assembly. Theporcelain material of a bushing may get damaged and crackif the bushing is not handled with care. The following stepsshould be followed to replace a bottom-connected bushing orits gasket:

1. First, the tank should be vented to the atmosphere untilthe pressure becomes zero.

2. Next, the liquid level must be lowered to a point thatallows the bottom disconnection of the lead.

3. Now, the nuts and washers used to clamp the bushingflange must be removed to free the bushing.

4. Finally, the bushing may be pulled outward to remove thebushing.

The cable may or may not have enough slack to perform bushing replacement through the wall. However, in the circumstances where this is not possible due to insufficient cable slack, a worker may gain access to the connections through the manhole.

When reinstalling the bushing, the new gasket should beinstalled in the gasket recess on the underside of the flange orthe mounting flange; this ensures that the gasket is properlyseated in the groove and is ready for operation. A lock washerand a flat washer should be placed between the flange and themounting nut. Ensure the nuts are finger-tight beforetightening each nut with a torque of 60±5 in-lbs. Aftercompleting this step, a pressure test must be applied to thetransformer. Supplementary leaflets that form a part of thecomplete instruction book are provided for condenser-typebushings units.

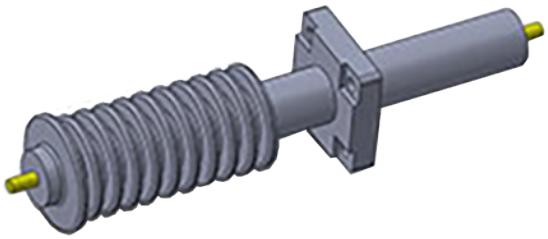

Figure: Transformer High-Voltage Bushing

Low-Voltage Bushings

through the cover or the tank side wall. Porcelain, cast resin,or cycloaliphatic epoxy bushing are used. Only flexibleconnections should be made to the bushing terminal to avoidexcessive mechanical loading. A bushing is used for makingconnections. It should never be used as a support or structuralmember to other current-carrying components of thetransformer assembly. Rigid connections between bushings and other bus supports should be avoided to prevent thermalexpansion forces from deforming the bushings. Contact yourfactory representative for guidelines on the proper repairprocedures in case a bushing gets damaged or starts leakingtransformer coolant. If a bushing replacement is required,follow the guidelines shown under High Voltage Bushings.

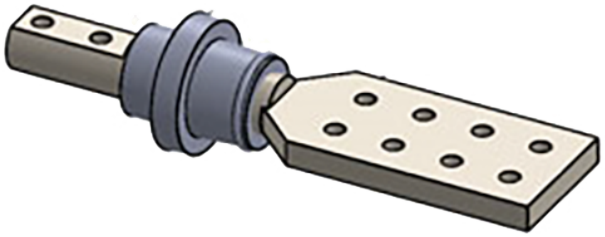

Figure: Transformer Low-Voltage Bushing

De-Energized Tap Changer

Tap-changers provide a means of changing the transformer'sprimary to secondary winding ratio and, thus, the relationship(voltage ratio) between the input and output voltages of theunit. Tap-changers can be operated using a rotatable handle atthe side of the transformer unit to influence the voltage ratioof a de-energized transformer without breaking thetransformer seal. A single tap-changer is typically set to aboutfive or seven positions, each corresponding to a differentvoltage ratio profile. More information on the voltage profilesat different tap positions can be found on the transf transformer instruction nameplate and the tap-changer dial plate.

WARNING:

Never operate a tap-changer on an energized transformer unit.Changing the tap positions on an energized transformer canresult in severe personal injury and equipment damage.

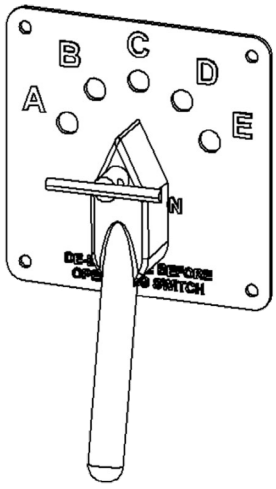

Figure: De-energized Tap Changer.

Transformer Conservator

All free-breathing transformers that do not have a conservatorinstalled have a headspace above the oil level inside theirtanks filled with a gaseous mixture. The existence of thisheadspace allows for the contraction and/or expansion of theoil volume that results in the transformer loading andenvironmental (cooling and/or heating) conditions.

Transformers installed with conservators are consideredimmune to air moisture/ humidity because the rubber bladderinside the conservator prevents the oil from coming intocontact with the ambient air. In practice, the transformer oil isprotected from ambient air for as long as the bladder remainsintact.

Maintenance

Periodic inspection

1. External: The paint and finish on the outer body of thetransformer should be checked periodically, especially ifthe unit must be exposed to inclement atmosphericconditions. If there is evidence of weathering, the tankshould be cleaned thoroughly, any spills of the insulatingliquid on the surface should be wiped off, and factoryapprovedpaint should be applied to repaint the exterior. The tightness of the bolted joints should be occasionallyinspected for signs of looseness and tightenedaccordingly.

2. Gauges and similar accessories perform many vitalsensing tasks that help workers monitor and maintain atransformer unit. Therefore, all gauges should beinspected as regularly as possible. Some importantconsiderations for inspecting gauges are as follows:

- The liquid level must continue as normal, even under the effects of the operating temperature.
- If the pressure gauges indicate zero pressure for prolonged periods, look for signs of gas leakage.
- Under normal operating conditions, the liquid or winding temperature should never rise higher than the design value as shown on the transformer nameplate, plus the ambient temperature in the transformer location.

3. Periodically collect and analyze liquid samples from thetransformer, as described in this manual's "Sampling"section. A log of the test values should be kept andupdated regularly to determine when replenishing orreconditioning services may be required.

Removing and Replacing Bushings

Two general categories for constructing bushings are "drawlead" types and "bottom connected" bushings. Bottomconnectedbushings have a fixed internal spade or a centerstud. Both of these bushings are shown in the figures below.

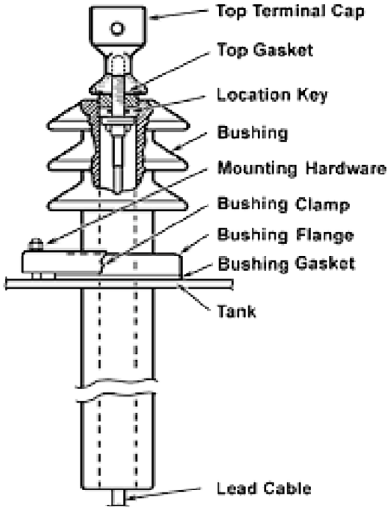

Figure: "Draw lead" type bushing.

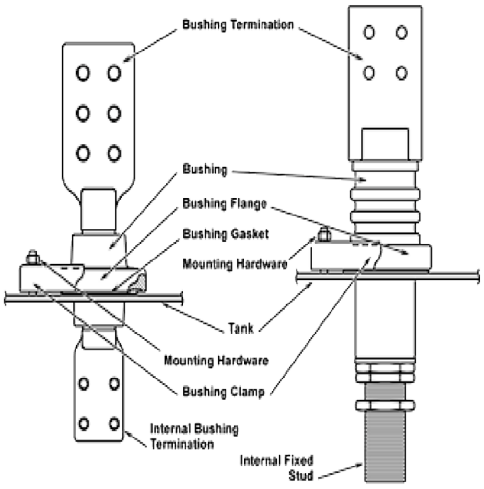

Figure: Fixed stud and spade-type bushings.

The bushings removal procedure will differ depending uponthe type of construction. These two methods are describedseparately in the written material that follows. Standard safetyprecautions must be observed before any work commences.

WARNING:

Always take appropriate precautions before working with thetransformer bushings to increase worker safety.

- Ensure the transformer is completely de-energizedand disconnected from the rest of the system toprevent accidental re-energization.
- Ground all transformer circuits to discharge anystored energy into the ground before workers operateon the device.

Failure to take these precautions can result in severe personal injuries, equipment damage, and even death.

Additional Precautions Include the Following:

- Lock the disconnect switches in the “open” positionto cut off the supply lines on the primary andsecondary sides of the transformer.
- Bring the tank to ambient pressure if the transformeris under vacuum or pressure.
- Check the liquid level inside the transformer tank.Lower the oil sufficiently to prevent loss of oil whenthe bushing is removed.
- Always store the extracted bushings in dry, clean,and sealed containers to protect them fromatmospheric conditions and contaminants. Returnany removed liquid to the transformer tank.

Steps for Removing and Replacing Draw Lead Type Bushings

All free-breathing transformers that do not have a conservatorinstalled have a headspace above the oil level inside theirtanks filled with a gaseous mixture. The existence of thisheadspace allows for the contraction and/or expansion of theoil volume that results in the transformer loading andenvironmental (cooling and/or heating) conditions.

Transformers installed with conservators are consideredimmune to air moisture/ humidity because the rubber bladderinside the conservator prevents the oil from coming intocontact with the ambient air. In practice, the transformer oil isprotected from ambient air for as long as the bladder remainsintact.

Removing

1. Unscrew the top terminal cap and remove it to expose thethreaded stud end of the “Draw Lead” cable. Sometimes,a pin may hold the threaded stud in place. Remove thispin as well.

2. Fasten a pull wire, rod, or cord to the threaded stud andguide the lead through the bushing’s bore as the bushingis raised. Ensure the lead does not fall into the openingcreated once the bushing is removed.

3. Remove the bushing flange mounting hardware to freethe bushing for removal.

4. Finally, remove the bushing and guide the “Draw Lead”terminal stud and conductor through the base of thebushing.

Replacing

Follow the removal procedure for the “Draw Lead” typebushing in the reverse order to replace/reinstall the bushing.Flange bolts should be tightened with torque levels asspecified in Table 1. The top gasket and the gasket installedunder the bushing mounting flange should be new or in goodcondition to make a positive seal. The mating surfaces for thegasket must be clean and smooth.The threaded stud must be keyed to the top of the bushing toprevent it from rotating during the tightening of the terminalcap.

The threaded stud must be seated correctly/precisely. Todo this, the stud should be pulled up and turned until it isproperly aligned and seated.

Table 1. Torque Values

Bushing Clamps	
4-hole Aluminum Cast Bushing Clamps	70-80 in.-lbs.
Molded Tri-Clamp Bushing	40-60 in-lbs.
All other 3- & 4-hole Bushing Clamps	40-60 in-lbs.
2-hole Bushing Clamps	55-65 in-lbs.
Internal Spade Bushings	
1/2” Steel (Grade 8)	50 ft-lbs.
3/8” Steel (Grade 8)	50 ft-lbs.
Internal Stud Bushings	
3/8 “-16 Brass Nuts	16 ft-lbs.
5/8 “-11 Aluminum Nuts	60 ft-lbs.
5/8 “-11 Brass Nuts	75 ft-lbs.
1 “-14 Brass Nuts	121 ft-lbs.
Bushing Lead Block, ½” Steel Hardware	110 ft-lbs.

Steps for Removing and Replacing Fixed Stud or Spade Type Bushings

Removing

1. Ensure that all precautions described under this manual's"Removing and Replacing Bushings" section have beentaken before starting the removal process for theinspection cover (manhole) nearest the target bushing.The actual procedure consists of the following threesteps:

- First, remove all grease, dust, dirt, moisture, and foreignmaterial from the cover.
- Release the cover bolts and remove them from thesurface of the tank.
- Remove the cover by lifting it vertically to preventdamage to the bolt or cover gaskets.

2. Unfasten the bolted connections of flexible straps fromthe bottom end of the bushing stud.

3. Remove the bushing mounting flange nuts that hold themin place on the transformer tank.

4. Remove the Fixed Stud or Spade-type bushing from thetransformer.

Replacing

Follow the removal procedure for the "Fixed Stud" typebushing in the reverse order to replace/reinstall the bushing.Flange bolts should be tightened with torque levels asspecified in Table 1. The gasket installed under the bushingmounting flange should be new or in good condition to makea positive seal. The mating surfaces for the gasket must beclean and smooth. After the new bushing is installed andconnected, the inspection opening cover should be replacedto ensure the gasket is in good condition. Return any removedliquid to the transformer tank and check for the correct liquidlevel.

A pressure test should be performed on the transformer at 5psig. This Test can help confirm the integrity of the sealsabove the liquid level for all openings. A solution of water andsoap can be used to clearly indicate a leak, as this solutionwould create bubbles in the presence of a leak.

WARNING:

Only remove the manhole or handhole cover after ensuringzero pressure inside the transformer tank. Activate thepressure relief valve to vent the tank to zero pressure. Noncompliancewith these safety procedures can result inequipment damage, severe injuries to personnel, and evendeath.

CAUTION:

Always take precautionary measures to prevent dirt andmoisture particles from entering the transformer unit whileremoving the transformer manhole cover, handhole cover, oraccess cover for internal inspections and transformerservicing. Dirt and moisture particles can enter an open transformer unit and contaminate its insulating fluid.Contaminated insulating fluids can seriously damage the transformer unit and prevent it from operating properly.

WARNING:

Never open or service a transformer while the transformer isenergized, ungrounded, or connected to the system.Tampering with the transformer covers or cover seals whilethe device is still connected to the system, energized orungrounded, can lead to severe personal injuries, equipmentdamage, and even death.

Steps for Removing a Bolted-On Manhole or Handhole Cover

1. First, remove all grease, dust, dirt, moisture, and foreignmaterial from the cover.

2. Manually operate the pressure relief valve to relieve theinternal tank pressure.

3. Remove the hardware that attaches the cover to the tankusing appropriate tools.

4. Now, pry the cover gently upward to ensure the covergasket does not come into contact with the transformerinsulatingliquid. Lifting the cover vertically can alsohelp prevent damage to the bolts, cover, and tank gasket.

5. Finally, remove every gasket section from the manholeflange while noting each piece's orientation (up/down)and location.

Steps for Reinstalling a Bolted-On Manhole or Handhole Cover

1. First, return the previously removed gasket sections totheir original locations and orientation in the manholeflange.

2. Now, reinstall the manhole/handhole cover by tighteningthe cover hardware in their required places by applying25 ft-lbs. of torque. After installing all the nuts, re-torqueeach nut to ensure they are tightened properly, and theproper torque is achieved.

3. Next, remove the pressure relief valve, repressurize theheadspace, and check for leaks. If the cover wasreinstalled correctly, the tank pressure should not exceed7 psig. If the sealing is done properly, the establishedpressure inside the tank should be maintained for at leastfour hours.

4. Reinstall the access cover and use 25 ft-lbs. of torque totighten the access cover hardware in the requiredlocation.

Insulating Liquid Maintenance

Sampling Insulating Liquid

NOTE:

Liquid samples should be collected from the sampling valvelocated at the bottom of the tank, and they should only betaken when the transformer unit is warmer than the air in itssurrounding area to prevent the moisture from condensing onthe liquid. The liquid samples should be collected in dry and clean glass bottle containers with large mouths. It should beensured that the fluid does not splash into the receivingcontainer as it is being collected because it could introducemoisture and air into the fluid. Before starting the collectionprocedure, rinse the bottle at least three times with the liquidbeing sampled and ensure the collected samples adequatelyrepresent the qualities of the liquid inside the tank.

WARNING:

Never allow the fluid level inside the tank to go lower thanthe low-level indicator on the liquid level gauge. Insufficientfluid increases the risk of unit failure, which could result insevere personal injuries, equipment damage, and even deathof exposed personnel.

Testing Insulating Liquid

Follow the procedures for testing the dielectric strength ofinsulating liquids, as specified by the guidelines provided bythe American Society for Testing Materials (ASTM) in theirstandard ASTM D-877, "Standard Method for TestingElectrical Insulating Oils.

"The dielectric strength of the liquid should never be allowedto drop below 26 kV. If it drops below this level at any time,the liquid should be filtered and dried until it tests at 30 kV orbetter once again.

Filtering Insulating Liquid

A filter press is a very effective filtering tool that can be usedto filter Transformer oil, R-Temp fluid, or Envirotemp FR3™fluid. A filter press can filter all foreign matter from the fluid,including small amounts of moisture and finely dividedcarbon particles. The filtering assembly includes aspecifically proportioned filter press, strainer, gauges, dryingoven, necessary piping, valves, driving motor, combined drippan and mixing tank, and a positive volume gear pump. Thefluid should be filtered until the dielectric strength of the fluidreaches at least 30 kV or better.

CAUTION:

Ensure the filtering equipment that filters the insulating fluidis free of contaminants and other liquids. The presence ofother liquids in the filtering equipment may alter the electricaland physical characteristics of the fluid.

Applicable Standards

1. American Society for Testing and Material (ASTM) Standards:

- **Specification #D 877** "The Standard Method of Testing Electrical Insulating Oils".

2. Institute of Electrical and Electronics Engineers (IEEE) Standards:

- **IEEE Std C57.121™-1998** "Guide for Acceptanceand Maintenance of Less Flammable HydrocarbonFluid in Transformers".
- IEEE Std C57.106™-2006 "Guide for Acceptanceand Maintenance of Insulating Oil in Equipment".
- IEEE Std C57.93™-2007 "Guide for Installationand Maintenance of Liquid Immersed PowerTransformers".
- IEEE Std C57.91™-2011 "Guide for LoadingMineral Oil Immersed Transformers".

R-Temp Fluid-Filled Transformers

The periodic maintenance tests should be performed for an RTempfluid-filled transformer with the same frequency andschedule as that for a conventional mineral oil-filledtransformer with a similar application. The same techniquesshould also be used to collect the samples in both cases. Thebasic recommended tests for R-Temp fluid-filledtransformers are moisture content, dielectric strength, andflash and fire point.

Dielectric Strength

Although a transformer should operate satisfactorily evenwith the dielectric strength of its fluid lowered to 22 kV, anR-Temp fluid with a dielectric strength below 25 kV indicatesthat the fluid is excessively contaminated and that it shouldbe filtered or replaced to remove the particulate or moisturecontaminations from affecting transformer operations. Thedielectric strength of the R-Temp insulating fluid should betested according to the guidelines of ASTM D 877.

Flash and Fire Points

R-temp fluid's flash and fire point change drastically witheven relatively small percentages (2-3%) of transformer oil orcontaminants in the fluid. If there is suspicion that the fluidmay have been compromised due to contaminations, the flashand fire point of the fluid can be measured by following theguidelines provided in ASTM D-92. If the measured fire pointis lower than 300°C, the fluid must be contaminated with alower fire point material. Retro-filling may be required if theflash or fire points of the fluid fall below the requiredminimum values.

Drain and Refill

When draining and refilling the transformer tank, special caremust be taken to stop gas bubbles from becoming entrappedin the fluid/system. Sufficient settling time must be providedbetween the fluid refilling and the transformer energization sothat any gas bubbles that do become entrapped can dissipatefrom the system naturally.

FR3™ Fluid-Filled Transformers

The periodic maintenance tests should be performed for anFR3™ fluid-filled transformer with the same frequency andon the same schedule as that for a conventional mineral oilfilledtransformer having a similar application. Additionally,the same techniques should be used to collect the samples inboth cases, as well as underlined in ASTM-D923. The basicrecommended tests for FR3™ fluid-filled transformers aremoisture content, dielectric strength, and flash and fire point.

The Acceptance values for these tests should meet or exceedthe requirements set in IEC 61203, “Guide for Maintenanceof Transformer Esters in Equipment”.

CAUTION:

If the insulating fluid has a temperature of less than –10°C(14°F), then the energized load-break switches and the noloadtap changers should not be operated, and the Bay-O-Netfuses should not be used to break or make a load. Operationsmay be possible at lower temperatures if it is certified by themanufacturer of the switching device for load-breakoperations in Envirotemp™ FR3™ fluid.

If the transformer manhole must be removed for internalservice and maintenance, the exposure time of the internalside of the transformer to ambient air should be kept to aminimum and should always be kept lower than 24 hours.Circulation of dry air inside the transformer is recommendedwhenever the unit is exposed to the atmosphere. The manholeor cover should be replaced immediately after the service andmaintenance work is completed, and the headspace should bepurged and recharged with dry nitrogen. The purging andrecharging procedure should include the following steps:

1. The headspace should be filled with dry nitrogen at2 to 3 psig pressure.

2. The headspace should be vented to atmosphericpressure.

3. The headspace is refilled with nitrogen to 2 to 3 psig.

4. The hermetical sealing of the transformer should beensured, and its quality should be checked.

If the transformer manhole cover or the non-flapper style Bay-O-Net fuses are removed for more than 24 hours, the oxygen absorber packet(s) installed on the transformer device should be replaced.

Spare Parts

MPS has expertise in custom transformers and only makes alimited number of units based on a single design. MPS alsomakes replacement parts on a case-by-case basis. If a unitneeds a replacement part, the customer should contact theMPS factory and provide all the unit’s nameplate data.

Preventive Maintenance Instructions

The transformer unit is a static device whose operationconditions may exceed the specified normal operatingstandards. Depending on the duration and intensity of theseabnormal conditions, the transformer’s useful service life candeteriorate. This section provides practical procedures andsteps to take to maintain and service a transformer device tohelp increase the service life of the transformer device.

Exterior Maintenance

Items to be Inspected	Points to be Checked	Remedial Actions	Frequency
Exterior Surfaces	Inspect the exterior surfaces for signs of damage, battered metal, gouges, tampering, etc. Check damages that could allow wires and other metallic devices to enter the transformer body.	Promptly repair any damages found on the exterior surface.	Yearly
Paint or Protective Coatings	Inspect for scratches or weathering.	Any damage to the paint or protective coatings should be touched up immediately.	Yearly
Tank Leaks	Inspect the transformer tank for leakages.	Promptly repair any damages found on the exterior source.	Yearly
General Location	Check the surrounding area of the transformer device for stored materials, equipment, tools, or debris.	Remove anything found lying on, against, or near the transformer.	Yearly
General Location	Walk around the transformer unit and listen for noises other than a smooth humming sound. There should not be any intermittent rattling noise.	If found, abnormal noises should be promptly reported and investigated.	Yearly
Pad	Inspect the tilt angle of the pad support. It should be such that it does not cause the transformer to tilt more than 2°from the horizontal.	Repair the pad support immediately if it is compromised or out of level greater than 2°.	Yearly
Nameplates	Inspect the transformer nameplates and decals for abnormal or unexpected fading.	Contact your MPS representative to order a replacement nameplate or decals as required.	Yearly
Unusual Odors	Inspect the vicinity of the transformer device for smells of fluid or burning. Such smells are indicative of an undetected leakage under the base. The concrete around the transformer base should also be inspected for signs of oil spots.	If found, the abnormal odors should be promptly reported and investigated.	

Interior Maintenance

Items to be Inspected	Points to be Checked	Remedial Actions	Frequency
Gauges and Controls	Check the operations of these devices.	Repair or replace an equipment or device if it does not operate as expected. No damaged or defective equipment should be operated during the transformer service.	Yearly
Equipment Leaks	Inspect fuse mountings, switches, drain cocks, and plugs. Search tank-wall seals, gaskets, and similar equipment for signs of insulating liquid seepage.	Make all possible repairs if a device is found to be damaged. Replace seals and gaskets in the tank wall after opening the tank and lowering the liquid to an appropriate level. Refer to the Insulating Liquid Maintenance section for instructions on opening the transformer tank, draining the insulating liquid, and refiling it after the work.	Yearly
Tank Pressure	Check the vacuum/pressure gauge and ensure it does not remain at zero for an extended period. Preferably, the given unit should not cycle between positive and negative pressures daily. If any of the readings are observed to be lower than -2 psig or greater than +7 psig, then the reading should be taken as an indication of an unwanted condition that should be corrected promptly.	The vacuum/pressure gauge remaining at zero for an extended period indicates that the transformer tank is not air-tight and that air is leaking out and into the tank. In such a case, a leak test should be performed to make the required repairs. To perform this Test, add nitrogen to the airspace, monitor the area for a minimum period of 12 hours, and observe for signs of pressure loss. If any pressure loss occurs, locate the leak and repair it immediately.	Yearly
Dielectric Fluid Level	Check the dielectric fluid level gauge. The notation of the gauge has the expected fluid level calibrated against an average internal fluid temperature of 25 °C. If the gauge shows a level above this zone, then the fluid level is normal when operating at full operational temperature. Such a reading does not indicate the transformer is operating at a temperature above the nameplate-rated value.	Check the transformer for leaks if the dielectric fluid level falls below the nominal level. If found, repair the leaks immediately and fill the tank with the oil needed to bring the fluid level to the nominal operating levels	Yearly
Fluid Temperature	Check the liquid temperature gauge to note down the elevated temperature of the fluid. If a drag hand exists, reset it and compare the elevated temperature value to those of similar transformer units. The maximum loading on the hottest day determines the maximum top-fluid temperature measured by the drag hand. A typical maximum reading can be calculated by subtracting 10 °C from the nameplate-rated temperature rise value and adding the maximum ambient peak for the given area. Example: 65 - 10 + 40 = 95 °C.	If the temperature value is elevated, the unit should be serviced immediately to identify the cause for the elevated value.	Yearly

Interior Maintenance

Items to be Inspected	Points to be Checked	Remedial Actions	Frequency
Cable Connections	Check for signs of overheating by looking for discolored spades (paddles) and loose connections. The tin plating on a terminal will have a rainbow-like coloring if the particular terminal is exposed to overtemperature conditions.	Find the loose connections and tighten them immediately. A qualified technician should immediately address any observed damage and discolorations on the device.	Yearly
Bushings	Inspect the condition of the LV and HV bushings. Observe these bushings for signs of breakages, dirt accumulation, heat damage, general damage, and flashovers. It should be noted that the excess dielectric grease from separable dead-front connectors can liquefy under heat and appear like an internal fluid leak.	Clean the bushings immediately to get rid of the dirt. A qualified technician should address any observed damage to the device immediately.	Yearly
Cubicle Padlock	Check all cubicles and ensure that all of them are locked.	If any locks are missing, replace them immediately.	Yearly
LV Bushing Cantilever	Check for stiff cable conductors and excessive cable weights that may put downward or upward pressure on the bushings due to pad settling	Adjust the conductor or cable position immediately to eliminate pressure.	Yearly
Pressure Relief Valve	Check their operation and look for signs of dirt and debris accumulation on the device.	Replace the device if it is damaged. Clean the device if it is dirty or clogged with debris.	Yearly
Lightning Arresters	Check for signs of breakage and damage on the device. Check the ground connection for tightness and intactness.	Replace any arresters that are damaged. Any loose ground connection should be secured and tightened.	Yearly

Dissolved Gas Analysis

Items to be Inspected	Points to be Checked	Remedial Actions	Frequency
Oil and DGA Samples	Collect oil samples from the transformer and send them to a third-party testing laboratory to check for their characteristics. For dissolved gas analysis (DGA) samples, request a DGA sampling kit from a third-party testing laboratory. Following the instructions, properly fill the syringe and return it to the lab for analysis.	Compare the results of the dissolved gas analysis tests to the baseline composition standards. Check the dissolved gas levels for abrupt changes. If any abrupt changes are found, investigate them immediately.	Yearly