INSTALLATION, OPERATION AND MAINTENANCE GUIDE

FOR INDOOR/OUTDOOR DRY-TYPE TRANSFORMERS WHICH UTILIZE A NJ6, NJ7 OR P SERIES ENCLOSURE

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Safety Precautions

(1) Do not lift or move a transformer without proper equipment and experienced personnel. Lifting provisions are provided on inside of enclosure on the core & coil only. Always use all lifting provisions provided by manufacturing.
DO NOT LIFT THE TRANSFORMER BY THE ENCLOSURE.
Rolling and skidding are recommended on transformers with a pre-ordered skidding base.

(2) Do not off-load the transformer until a full inspection has been completed.

(3) Use terminals only for electrical connections. Flexible connectors are recommended for bus connections. The transformer terminals are not designed to support the weight of supply or load cable. Uni-strut supports can be added in the field providing proper clearances are maintained.

(4) Connections should only be in accordance with the nameplate diagram or connection drawings.

(5) Make sure all power is disconnected before attempting any work on the transformer or inside of control box and ground all windings.

(6) Make certain all ground connections, line terminals and selected taps are complete and tightened before energizing the transformer.

(7) Do not attempt to change any taps - primary or secondary, while the transformer is energized.

(8) Do not change connections when the transformer is energized.

(9) Do not tamper with control panels, alarms, interlocks or control circuits.

(10) Do not adjust or remove any accessories or cover plates while the transformer is energized.

(11) No supply cables should come in contact with the core or any live part except the terminal that it is intended for. Ensure that minimum clearances are maintained. (refer to section 10 of Field Testing)

CONTENTS

SCOPE

This guide covers the recommendations for the application, installation, operation and maintenance of single and three phase dry-type transformers and iron core reactors with or without enclosure. It is emphasized that these abbreviated instructions should be used in conjunction with all standards covering such work and should be referenced accordingly.

These recommended practices are for general applications and any special requirements should be referenced back to the transformer manufacturer and/or their representative.

It is further recommended that installation work be governed by ANSI/IEEE C57.94. This is the IEEE Recommended Practice for Installation, Application, Operation and Maintenance of Dry-type General Purpose Transformers.

RECEIVING & INSPECTION

Before any equipment is off-loaded, transformers should first be inspected for correctness of shipping information. Confirm that the identifying part number on the nameplate of the transformer matches the packing list and Bill of Lading.

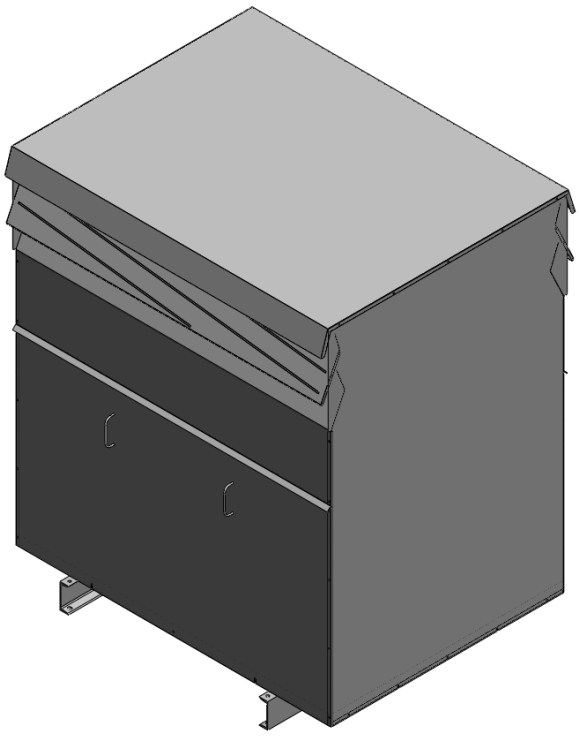
Inspect the transformers immediately upon receipt for evidence of damage or indication of rough handling that may have been caused during shipment.

Examination should be made before removing transformers from shipping vehicles. Inspection should also be made for any evidence of water or other contaminants that may have entered the transformer during transit.

A claim should be filed with the carrier at once and the manufacturer should be notified.

Ventilated dry-type transformers are shipped either completely assembled in a sheet metal enclosure or as a core and coil assembly with or without a separate enclosure. All parts and components are wrapped in clear plastic sheets and covered with a shipping tarpaulin. Drawings may also accompany the shipment in a separate package that detail assembly if required.

Once the unit has been received, remove the covers or panels and proceed with an internal inspection for any evidence of damaged or displaced parts, loose or broken connections, damaged terminal boards, dirt or foreign materials and for the presence of any water or moisture. If any damage is evident, contact the transformer manufacturer and/or your representative immediately.



NJ TYPE ENCLOSURE

LIFTING PROCEDURES

Lifting provisions are provided on all dry-type transformers. Lifting provision can be 2 or 4 of 5/8" (16 mm) or 3/4" (19 mm) shouldered eye bolts or a pair of lifting angles (see figure 1) based on the total weight of transformer. Shouldered eye bolts used for the unit weight is less than 15,000 lbs (6,804 kgs). Lifting angles used for the unit weight is 15,000 lbs (6804 kgs) and greater. Use of slings for an angular lift is strongly recommended.

Shouldered Eye Bolts

Lifting Angle

FIGURE 1

Procedure

Before a lift is made, the following instructions should be read and understood.

(1) Remove the roof of NJ type of enclosure (see figure 2) or lifting cover plate on roof of power enclosure (see figure 3).

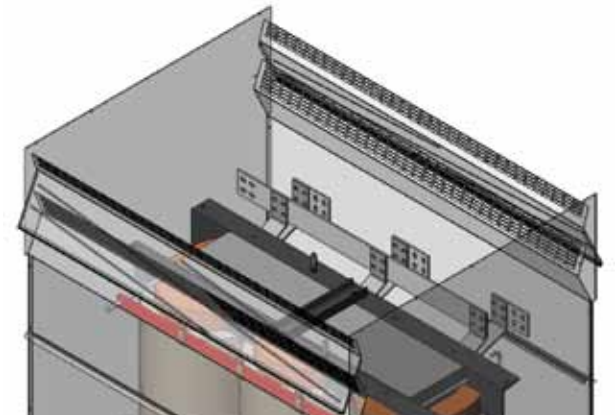


FIGURE 2

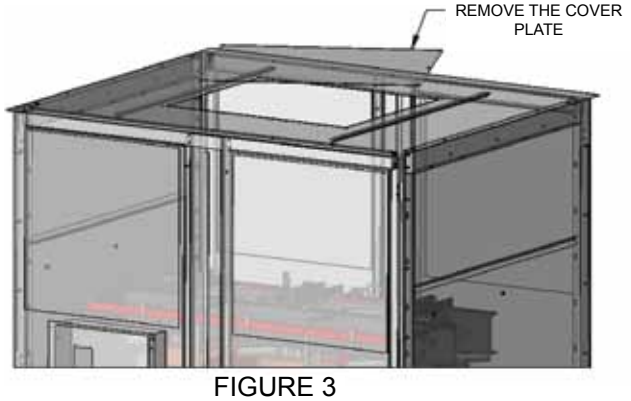


FIGURE 3

(2) Inspect that the lifting eye bolts or lifting angles are properly seated and tight.

(3) Verify lifting capacity of chains or slings, crane or other means refer to the weight of transformer on the nameplate.

(4) Measure the distance between the eye bolts or lifting angles (see figure 4 & 5).

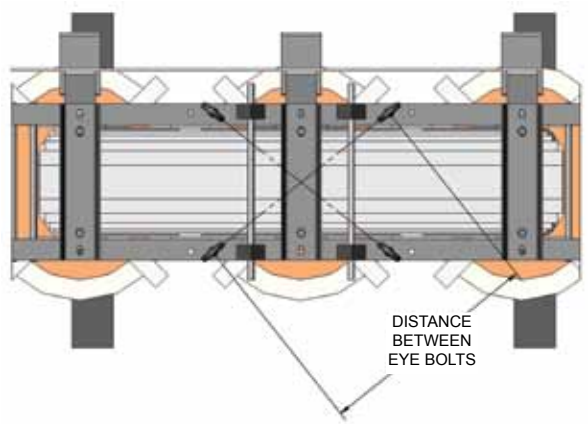


FIGURE 4

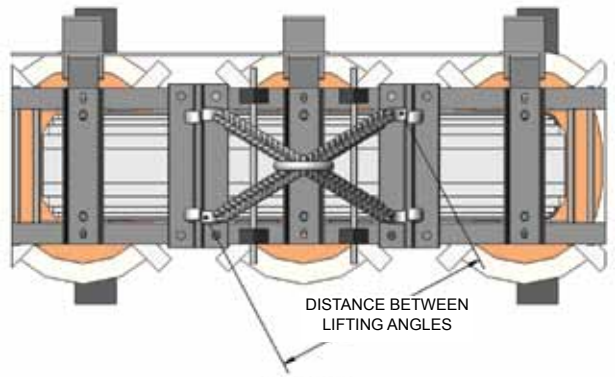


FIGURE 5

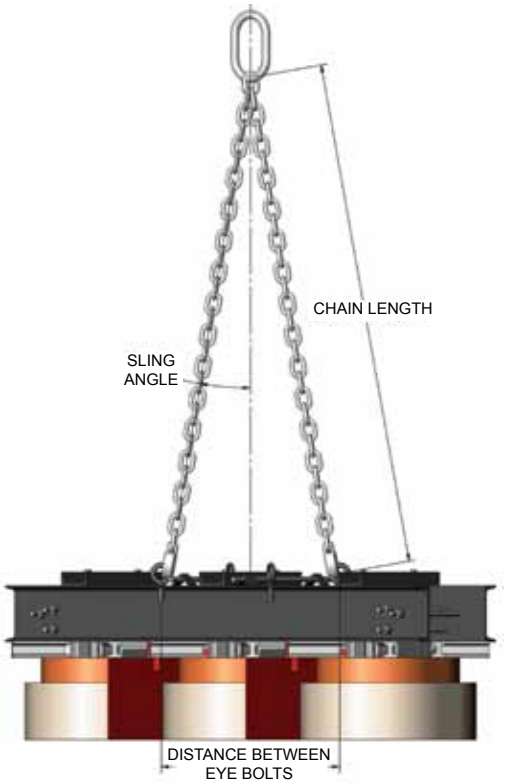


FIGURE 6

TABLE 1

*Eye Center	Chain Length (ft)							
	3’	4’	5’	6’	7’	8’	9’	10
10”	8°	6°	5°	4°	3°	3°	3°	2°
12”	10°	7°	6°	5°	4°	4°	3°	3°
14”	-	8°	7°	6°	5°	4°	4°	3°
16”	-	10°	8°	6°	5°	5°	4°	4°
18”	-	-	9°	7°	6°	5°	5°	4°
20”	-	-	10°	8°	7°	6°	5°	5°
22”	-	-	-	9°	8°	7°	6°	5°
24”	-	-	-	10°	9°	8°	6°	6°
26”	-	-	-	10°	9°	8°	7°	6°
28”	-	-	-	-	10°	8°	7°	7°
30”	-	-	-	-	10°	9°	8°	7°
32”	-	-	-	-	-	10°	9°	8°
34”	-	-	-	-	-	10°	9°	8°
36”	-	-	-	-	-	-	10°	9°

*Note: Distance between lifting eyes on front and rear frames

(5) Ensure that the sling angle is less than 10 degrees (see figure 6 & table 1).

(6) The direction of the pull (sling line) must be in-line with the plane of the eye bolts. When lifting a transformer with a 4-legged sling, align all four eyebolts to the center of the unit (see figure 5). When lifting a unit with a 2-legged sling, ensure that the eye bolts are installed at opposite corners of the unit and align to the center of the unit (see figure 7).

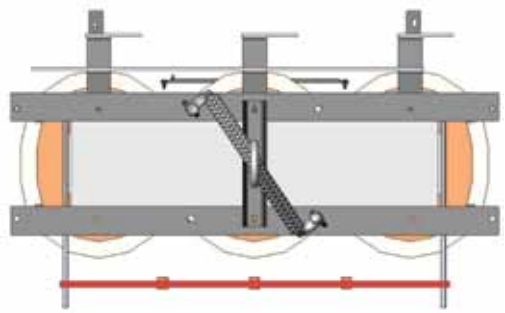


FIGURE 7

(7) Always use all the eye bolts or lifting holes provided in angles when making a lift to avoid overrating of bolts or torsion of frames.

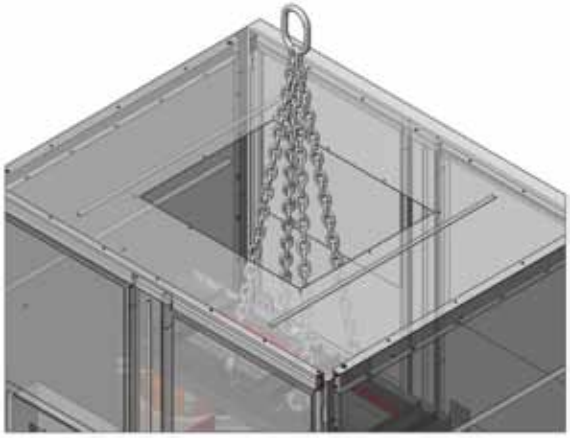


FIGURE 8

(8) Lift the power transformer by core & coil only through cutout in enclosure roof (see figure 8).

Do not lift transformer by the enclosure.

Do not lift power transformer with shipping hooks.

Do not lift transformer from beneath the enclosure.

Do not jerk lift to avoid mechanical stresses.

Do not push, drag or pull the transformer directly on the floor unless it is supplied with skid base.

STORAGE

Units must be stored in a warm, dry location, free of dust or air borne contaminants. The relative humidity to which the electrical insulation materials are exposed should be kept as low as practical. It is preferred to store in warm dry location to avoid moisture issues but may be able to be stored in temperature to -40°C (104°F). Transformer may be energized when the coil temperature is as low as -25°C (-13°F) but it is recommended they not be loaded until the coils reach 0°C (32°F). Fluctuating temperatures can cause condensation issues requiring a Dry-Out procedure. The floor on which the transformer is stored should be impervious to the upward migration of water vapor. Take precaution to guard against water from any source such as roof leaks, broken water or steam lines, windows, etc. It is not recommended that dry-type units be stored outdoors. If that is unavoidable, units must be well protected from snow, rain and other elements. Protection should include an initial wrap of first quality canvas with a final outside covering of plastic tarpaulin. It would also be desirable to include a desiccant such as a silica gel dry-out system to reduce the moisture content inside the assembly. If units are stored outdoors, dry-out is recommended as described on the following page.

INSTALLATION PRECAUTIONS

(1) It is recommended that anti-vibration pads or other vibration isolation devices be present when installing dry-type transformer. Some dry-type transformers may have pre-installed anti-vibration pads or other vibration isolation devices. Most of the time the anti-vibration pads are provided with the dry-type transformers and need to be installed on site. When installing the anti-vibration pads beneath transformer base beam, ensure that lifting the transformer by core & coil only. If the enclosure is provided and attached to the core & coil by shipping angles, make sure that the shipping hooks and shipping angles are removed in all locations (see figure 9 and 10) and then lift the transformer by core & coil only to install the anti-vibration pads (or other vibration isolations required per design).

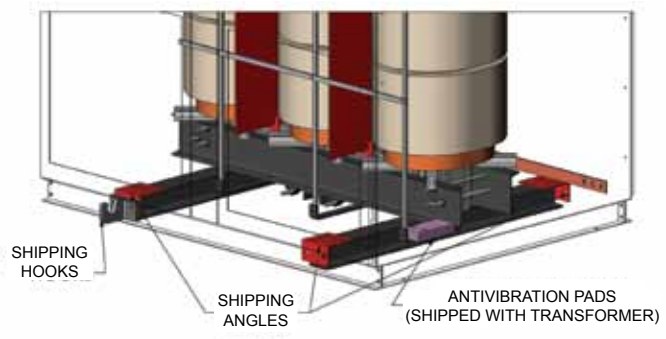


FIGURE 9

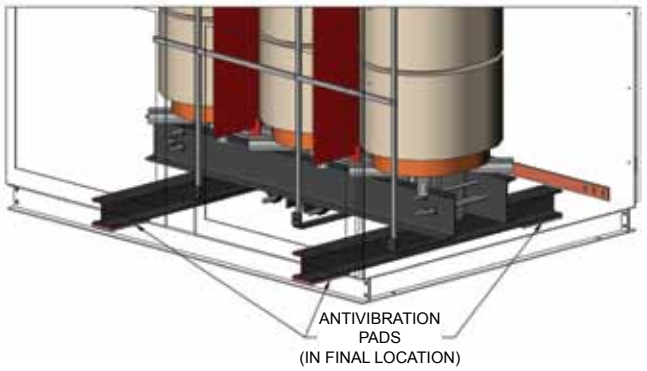


FIGURE 10

(2) Cable type, size and entry location shall confirm to Local Electrical Code.

(3) Terminals and terminal board shall not be used to support the weight of supply or load cables.

(4) Maintain the appropriate clearance between supply cables and live parts of transformer based on system voltages. (refer to section 10 of Field Testing)

(5) Use of flexible connectors for bus connections is recommended.

(6) Recommend the supply cables come in from bottom and/or side and shall not block ventilation openings.

(7) If any drilling needs to be done, please ensure that core and coil assembly must be protected by a cover sheet (e.g. Tarp) so that nothing can land on or in coil during or after drilling and when cover sheet is removed.

DRY-OUT

If a transformer has been exposed to moisture such as condensation or rain, or stored in a high humidity environment, the unit must be dried out prior to energization. First, immediately remove the transformer from service. Megger test at intervals to indicate a change is taking place with the moisture content in the insulation. Then proceed with any of the following dry-out methods:

(1) Free moisture should be blown or wiped off any Surface of the transformer to reduce the time of the dry-out period.

(2) Direct external forced air, hot or warmed, or radiant heat-up through the windings with all the ventilation openings cleared. Recommended temperature should not exceed 105°C (221°F). Continue this for a minimum of 24 hours or until all evidence of moisture or condensation is no longer visible.

(3) Electric heaters could be installed inside the enclosure - particularly for units stored outdoors. These heaters should be located under the windings on both sides of the core. If heaters are used, air circulation through the enclosure must still be permitted. Fiberglass furnace filters may be mounted temporarily over the inlet and outlet ventilation openings to minimize dust accumulation within the enclosure. These filters must be removed before the transformer is put into service. Recommended temperature should not exceed 105°C (221°F).

(4) For dry-out using internal heating through the shorted terminal method, please contact the transformer manufacturer for specific instructions. The principles of this method require to short circuit LV and supply current to HV no more than 100% of nameplate current rating. The winding temperature should not exceed 105°C (221°F) refer to section 4 of Field Testing.

(5) Variable factors affecting the construction and use of dry-type transformers makes it difficult to set limits for the insulation resistance. Experience to date indicates that 2 megohms, (one minute reading at approximately 25°C) per 1000 volts of nameplate voltage rating, but in no case less than 2 megohms total, may be a satisfactory value for insulation resistance. Insulation megger test (500 V or 1000 V DC). Tests to be done between:

LV to HV + Ground

HV to LV + Ground

Core to Ground (if the core is isolated)

It is emphasized that only specifically qualified personnel undertake this work.

Transformers that have been exposed to flood conditions, direct rain or sprinklers, may not be able to be dried out appropriately. Consult the manufacturer for further instructions.

LOCATION

Ventilated dry-type transformers normally are designed for installation indoors in dry locations. They will operate successfully where the humidity is high, but under this condition it may be necessary to take precautions to keep them dry from condensation if they are de-energized for appreciable periods. Refer to dry out instructions. Dry-type units covered by this guideline are designed for operation at altitudes not exceeding 1000 m (3300 ft.) unless transformer has been specifically designed for higher altitude.

Environmental Considerations:

Ventilated dry-type transformers should not be located in environments containing contaminants including dust, fertilizer, excessive moisture, chemicals, corrosive gases, oils or chemical vapors. Locations where dripping water is present are to be avoided. If this is not possible, suitable protection must be provided to prevent water from entering the transformer enclosure.

Dry-type transformer should not be installed in areas accessible to the public unless specially designed for that.

Dry-type transformers can be located outdoors, but they must be designed especially for outdoor environmental protection. Suitable weather resistant and tamper-proof enclosures are required in locations where there is driven water, snow, dust and sand particles should be avoided. Consult the transformer manufacturer for further information.

Transformer with open bottom, should not be installed on or over combustible surfaces.

Ventilation:

Transformers must be located at least 2 feet away from walls, obstructions, adjacent transformers or other reflecting surfaces on ventilation side unless otherwise marked. Or further if there is another heat source.

Directed air in the room near the transformer can disturb the natural air flow for cooling through the winding.

Adequate ventilation is essential for the proper cooling of transformers. Clean, dry air is desirable. If the location has unusually high airborne contaminants, optional filters may be required. If transformers are installed in vaults or other places with restricted air flow, sufficient ventilation shall be provided to maintain correct air temperatures. The limits are specified by CSA or ANSI standards and are measured near the transformer ventilation openings. The area of ventilation openings required depends on the height of the vault or transformer room and the location of transformer ventilation openings. For self-cooled transformers, the required effective area must be at least one square foot each of inlet and outlet per 100 kVA of rated transformer capacity, after deduction of the area occupied by screens, gratings, or louvers.

This is necessary to provide sufficient free circulation of air through and around each unit. This will also

permit ready access for maintenance.

If the transformer is to be located near combustible materials, the minimum distance established by The Local Electrical Code should be maintained.

SOUND LEVELS

The audible sound produced by transformers is due to energizing of the core by the alternating voltage applied to the windings. This creates vibrations whose fundamental frequency is twice the frequency of the applied voltage. The vibrations producing audible sound can occur in the core mounting and in the housing. The transmission of sound from the transformer can be by various media such as air, metal, concrete, wood or any combination. Amplification of audible sound can occur in a given area due to the presence of reflecting surfaces or mounting surfaces.

Sound levels for transformers can vary from 60 dBA for a 500 kVA to 76 dBA for a 10,000 kVA and more.

These sound levels are determined by CSA and ANSI Standards and are based on the following:

- **Sound levels specified are for a non-loaded condition at rated voltage and frequency**
- **Units are tested in a low ambient noise environment**
- **Walls or reflecting surfaces are at least 10' away from all sides of the transformer.**

It should be noted therefore that operating transformers when connected to a load, will exhibit higher sound levels than the standards referenced. Additionally, transformers are frequently installed in more confining electrical rooms which will have the effect of increasing the apparent sound level. Transformers will exhibit higher than normal sound levels if installed on suspended floors that may resonate. It is a good practice to install power units on the ground floor or basement level to avoid suspended floors and away from office or living quarters. Vibration dampeners or spring isolators are also recommended to attenuate sound levels.

Flexible connectors can be installed between the bus bars and other equipment to avoid vibration transfer. Ensure all mounting bolts are tightened and that the transformer housing is securely assembled and separate from the transformer itself.

Transformers installed in close proximity to each other can experience a resonant frequency between them that results in higher than normal sound levels.
If noise levels are a factor in the location of any transformer, special consideration should be given to the installation site and attenuation equipment. Interrupting the sound transmission medium with the installation of sound absorbing foam or fiberglass material on the ceiling or walls, could be considered.

GROUNDING

All non-current carrying metal parts in transformers must be grounded, including the core and enclosure. Standard construction has the core grounded through direct contact with the clamping structure. Cores that have metal bolts passing through them are insulated from the core clamps and grounded at a single point. Isolating the core in this manner is necessary on these transformers only to determine if there is an insulation failure in any through-bolts that might cause a high circulating current or hot spot. There are no requirements for isolating cores in any standards including UL, ANSI, CSA, IEEE and IEC.

FIELD TESTING

It is recommended that separate field testing and inspection be made before placing a transformer in service to determine that it is in satisfactory operating condition and to obtain data for future comparison. Tests and procedures as recommended in ANSI/IEEE is recommended as a minimum.

Where low-frequency applied-voltage, induced-voltage, insulation resistance or megger, for acceptance are conducted the test voltages shall not exceed 75% of factory test values. When field tests are made on a periodic basis, it is recommended that the test voltages be limited to 65% of factory test values. Disconnect surge arrestors if supplied. It is emphasized that any tests should be conducted by competent or qualified personnel in accordance with recognized safety standards and codes, particularly NFPA 70E or CSA Z462.

(1) If the transformer has been shut down for a period of time, it must first be visually inspected for evidence of condensation or moisture, also dust and dried out as described earlier.

(2) Fans, motors, relays and other devices should be inspected to be certain they are working correctly. Accessories such as lightning arresters must be installed in accordance with the assembly drawing provided.

(3) Verify the selection of taps, as per the nameplate and ratio the connections - all taps should be in the identical position on each coil (note there may be more than one set of taps on coil). Taps can only be changed when the unit is de-energized.

(4) Some units are provided with winding temperature equipment. An instruction manual, complete with drawings, will have been provided. These devices consist of a temperature indicator and a thermal sensing bulb. Ensure that all parts have been assembled and installed correctly. Failure to install this sensing bulb into the correct insulated sleeve can result in severe damage to the transformer. Maintain electrical clearance if installing sensing probes from the temperature monitor or terminal block. For winding > 30kV BIL, do not put probe in the coil unless instructed to do so.

Thermowell stick type

Thermowell tube type

(5) Check for tightness and cleanliness of all electrical connections including taps, phase connections and grounds.

RECOMMENDED BOLT TORQUE FOR BOLTED ELECTRICAL CONNECTIONS

BOLT SIZE	CARBON ST. GRADE 5 ft-lbs [Nm] ±5%	BRASS ALLOY CU270 ft-lbs [Nm] ±5%	S.S STEEL B8 OR B8M ft-lbs [Nm] ±5%
1/4-20 UNC	7 [10]	3.8 [5]	5 [6]
3/8-16 UNC	25 [28]	14 [18]	15 [20]
1/2-13 UNC	60 [70]	33 [45]	37 [50]

***Note: The above torque values are for dry, unlubricated bolts.**

(6) An insulation resistance test (Megger Test) should be conducted on each unit. It determines the integrity of the insulation. An insulation resistance test is of value for future comparative purposes and for determining the suitability of the transformer for a high potential test. This test should be completed before the high potential or Hi-Pot test.

Variable factors affecting the construction and use of dry-type transformers makes it difficult to set limits for the insulation resistance. Experience to date indicates that 2 megohms, (one minute reading at approximately 25°C) per 1000 volts of nameplate voltage rating, but in no case less than 2 megohms total, may be a satisfactory value for insulation resistance. Insulation megger test (500 V or 1000 V DC). Tests to be done between:

LV to HV + Ground

HV to LV + Ground

Core to Ground (if the core is isolated)

Note: If the transformer core is isolated, then the core strap between the core and the top core clamp, must be disconnected before taking the reading from core to ground.

(7) Polarity or phase relation.

(8) Resistance measurements of windings.

(9) Ratio test for full winding and for all tap positions.

(10) Ensure that minimum clearances are maintained for all current carrying parts including windings, internal cable connections, NGR, CT's, auxiliary transformer and bus bars.

The following table may be used as a guide for minimum clearance for altitude not exceeding 1000 m (3300 ft). Above 1000 m (3300 ft) consult factory.

Transformer Voltage Class	Minimum Clearance (mm)	Minimum Clearance (in.)
1.2 KV	25	1
2.5 KV	50	2
5.0 KV	100	4
8.7 KV	130	5.3
15 KV	200	8
18 KV	250	10
25 KV	300	12
34.5 KV	400	16

Note: "Some specific component parts of a transformer may require clearances different than those indicated above. For those exceptions, you should comply with the instructions provided in the assembly drawings or installation procedure."

MAINTENANCE

CAUTION

The transformer must be de-energized prior to any maintenance. It is also recommended that all terminals be grounded.

FAILURE TO DE-ENERGIZE THE TRANSFORMER BEFORE OPENING THE ENCLOSURE COULD RESULT IN SERIOUS PERSONAL INJURY OR DEATH

Periodic Inspection and Maintenance:

Generally, very little maintenance is required for dry-type transformers. However, periodic care and

inspection is required to ensure long-term, successful operation. The frequency of inspection will depend on the conditions where the transformer is installed.

For clean, dry locations, an annual inspection is normally sufficient. For other locations where the air is contaminated with dust or chemical vapors, inspection at three or six month intervals may be required.

With the transformer de-energized, remove all access panels on the enclosure and ground the terminals. Inspect for dirt particularly on insulating surfaces or any surface which tends to restrict air flow. Insulators, terminals and terminal boards should be inspected for discharge (tracking), breaks, cracks or burns and tightness of hardware. It is necessary to clean these parts to prevent flashover due to the accumulation of the contaminant.

Evidence of rusting, corrosion, and deterioration of the paint should be checked and corrective measures taken where necessary. Fans, motors, and other auxiliary devices should also be inspected and serviced.

CLEANING

If excessive accumulation of dirt is apparent on the transformer windings or insulators, the dirt must be removed to permit the circulation of air. Particular attention should be given to cleaning the top and bottom ends of the winding assemblies and to cleaning ventilation ducts.

The windings may be cleaned with a vacuum cleaner, blower, or with compressed air. A vacuum cleaner is preferred as a first step followed by the use of compressed air. The compressed air should be clean and dry and applied at a relatively low pressure (not over 25 pounds per square inch). Leads, lead supports, coil support, terminal boards, bushings and other major insulating surfaces should be brushed or wiped with a dry cloth. The use of liquid cleaners is undesirable due to solvents which could have a detrimental effect on insulating materials.

FIELD SERVICE

The following is intended as a trouble shooting guide to help determine corrective measures for power transformers in the field. It is emphasized that only qualified personnel should be permitted to examine installed transformers. Transformer must be de-energized before any work is conducted on a transformer. It is also recommended that all terminals be grounded.

(1) Overcurrent

Fully loaded transformers may appear warm to the touch. Standards permit the temperature of the transformer enclosure cover to be 65°C (149°F) [80°C (176°F) in not readily accessible location] over ambient which at 40°C(104°F) ambient could be a maximum of 105°C (212°F) [120°C (248°F) in not readily accessible location] continuous. In this condition, the temperature on a thermometer could be at the maximum of 220°C (428°F).

When temperatures exceed this, overheating of the transformer occurs and damage may result. Check for these conditions:

- ➲ continuous overload or overloads for long periods
- ➲ wrong external connections
- ➲ excessive input voltage or current
- ➲ voltage or current harmonics
- ➲ poor room ventilation or heating from other

sources

- ➲ high ambient temperatures [standards permit 30°C (86°F) average, 40°C (104°F) maximum]
- ➲ blocked air ducts or ventilation openings
- ➲ accumulation of dirt and dust restricting air circulation.

(2) Noise and Vibration

Sound levels for power transformers can vary from 60 dB(A) for a 500 kVA to 76 dB(A) for a 10000 kVA. These sound levels are determined by national standards and are based on the following:

- ➲ values are for a non-loaded condition
- ➲ tested in a low ambient noise environment
- ➲ walls or reflecting surfaces at least 10' [3m] away from all sides of the transformer.

Transformers are frequently installed in more confining electrical rooms, and additionally, when connected to the load, will exhibit higher sound levels than standard. Excessive noise can be caused by:

- ➲ high input voltage
- ➲ high frequency
- ➲ unbalanced loads
- ➲ excessive load current
- ➲ voltage and current harmonics from nonlinear loads
- ➲ loosened core clamps
- ➲ hardware or enclosures loosened due to shipping or handling
- ➲ shipping plates are not removed
- ➲ anti-vibration pads are not installed
- ➲ transformer location

Transformers will exhibit higher than normal sound levels if installed on suspended floors that may resonate. It is a good practice to install power units on the ground floor or basement level to avoid suspended floors. Vibration dampeners or spring isolators are recommended to attenuate sound levels. Additionally, **flexible connectors** should be installed between the bus bars and other equipment to avoid vibration transfer.

Transformers installed in close proximity to each other can also experience a resonant frequency between them that will result in higher than normal sound levels.

(3) Reduced or Zero Voltage

Loose connections on transformer terminals or terminal boards, broken lead wires or shorted turns are possible sources. As well, reduced output voltage may be from an incorrectly selected tap position.

(4) Excess Secondary Voltage

Can be caused by higher input voltage or an incorrect tap position.

(5) Smoke from Transformer

Smoke and or fumes on start up is common and is the result of oils and lubricants used in the manufacturing process. The smoke is considered an irritant and should be temporarily ventilated. It is not a long term health risk.

(6) High Core Loss

Causes are high input voltage and/or lower frequency.

- ➲ gaps in the core due to shifting during shipment or handling.

(7) Burned Insulation or Insulation Failure

With evidence of burned insulation, check for the following:

- ➲ continuous overload condition
- ➲ excessive harmonics

- ➲ overheating due to ventilation
- ➲ lightening surge
- ➲ switching or line disturbance
- ➲ broken leads or arresters
- ➲ damaged terminals or terminal boards
- ➲ shorted turns or mechanical damage
- ➲ contamination (insulation failure)

If transformer cores show evidence of overheating and discoloration, insulation near the core may also appear discolored. Very high core temperatures are caused by:

- ➲ high input voltage
- ➲ lower frequency or saturation of the core due to voltage harmonics.

(8) Ferroresonance

Significant over voltages may occur on transformers due to the phenomena of ferroresonance. Ferroresonance is caused by both the use of single pole switching with ungrounded primaries and capacitor switching restrike.

The transient voltages generated are well in excess of the transformer's inherent ability to withstand over voltage. Transformers are designed to operate at 6% over voltage at rated load, and 10% under voltage at no load.

In order to reduce the risk and help protect the transformer, the user may want to consider that transformers operating at 60 kV BIL or higher, have metal oxide arrestors installed at the entry point to the transformer on all phases. This applies to either the primary or secondary, if either is rated 60 kV BIL or higher. Ferroresonance may cause significant damage to electrical equipment, particularly transformers and protection is recommended.

(9) High Exciting Current

Can be caused by:

- ➲ high input voltage
- ➲ low frequency
- ➲ shorted turns
- ➲ gaps in the core due to shifting during shipment or handling.

(10) Oscillatory Switching Transients

Occasionally, when a transformer is switched into or out of a system, a transient recovery voltage containing a large component of high frequency voltage will be subjected to the terminals of the transformer. This occurs most often when a vacuum breaker is used and is a direct result of the characteristic of the vacuum breaker to chop current. These current chops and subsequent re-ignitions produce a transient voltage at the terminals of the transformer that is oscillatory, of high frequency and prolonged duration. When this applied voltage has a frequency component near one of the natural frequencies of the transformer and of sufficient duration, internal damage to the insulation structure of the transformer will result.

When a transformer is used with vacuum or SF6 circuit breakers, we recommend that the system engineer reviews the possibilities of oscillatory switching transients and employs appropriate mitigating methods to avoid transformer insulation damage.

(11) Core Grounding

All non-current carrying metal parts in transformers must be grounded, and this includes the core. Transformer cores with through bolts must be insulated from the core clamps and grounded at a single point. Isolating the core in this manner is necessary to determine if there is an insulation failure

in any through-bolts that might cause a high circulating current or hot spot. There are no requirements for isolating cores in any standards including UL, ANSI, CSA, IEEE and IEC. Note: If the transformer core is isolated, then the core strap between the core and the top core clamp, must be disconnected before taking the reading from core to ground.

If there is a low megger reading, or low resistance between the core and ground on power transformers, causes may include:

- dirt, dust or moisture bridging the insulation between the core and the core frames
- shifted insulation due to shipping or handling.

(12) Coil Distortion

Short circuited coils exhibit severe distortion from their normal round or symmetrical appearance.

(13) High Conductor Loss

Overloads, or terminal boards not on the identical tap position can result in conductor heating.

(14) Breakers/Fuses Opening

Breakers and fuses opening can be caused by:

- overload conditions
- voltage or current harmonics
- short circuit
- insulation failure that causes excessive current.
- voltage too high when energized
- setting too low to allow for inrush current

(15) Excessive Cable Heating

Causes include:

- improperly bolted or crimped connections
- loose connectors
- loose lead wires or terminals
- incorrectly sized cables or terminals
- overload condition

(16) Moisture

If a transformer has been exposed to moisture such as condensation or rain, the unit should be dried out prior to energization. (refer to Dry-Out section on page 8) Hot or warmed air, radiant heat or internal heat should be directed through the windings. This should continue for 24 hours or until after the evidence of condensation is no longer visible.

Transformers that have been exposed to flood conditions, direct rain or sprinklers, may not be able to be dried out appropriately. Consult the factory for further instructions.

If any of the above conditions are evident, the transformer should be immediately removed from service. Corrective measure should be undertaken in consultation with the manufacturer representatives or qualified personnel.

After an evaluation has been completed, the transformer may be reenergized after the appropriate reworking, or the unit may have to be returned to the factory for further evaluation or repair.