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ELECTRICAL MACHINE WINDING TECHNICIAN

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

NAVTTC

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Contents

Introduction

Welcome to your Learner's Guide for the **Electrical Machine Winding Technician** Program. It will help you to complete the program and to go on to complete further study or go straight into employment.

The **Electrical Machine Winding Technician** program is to engage young people with a program of development that will provide them with the knowledge, skills and understanding to start their career in Pakistan. The program has been developed to address specific issues, such as the national, regional and local cultures, the manpower availability within the country, and meeting and exceeding the needs and expectations of their customers.

The main elements of your learner's guide are:

- **Introduction:**
  - This includes a brief description of your guide and guidelines for you to use it effectively
- **Modules:**
  - The modules form the sections in your learner's guide
- **Learning Units:**
  - Learning Units are the main sections within each module
- **Learning outcomes**:
  - Learning outcomes of each learning units are taken from the curriculum document
- **Learning Elements:**
  - This is the main content of your learner's guide with detail of the knowledge and skills (practical activities, projects, assignments, practices etc.) you will require to achieve learning outcomes stated in the curriculum
  - This section will include examples, photographs and illustrations relating to each learning outcome
- **Summary of modules**:
  - Thiscontains the summary of the modules that make up your learner's guide
- **Frequently asked questions**:
  - These have beenadded to provide further explanation and clarity on some of the difficult concepts and areas. This further helps you in preparing for your assessment.
- **Multiple choice questions for self-test**:

These are provided as an exercise at the end of your learner's guide to help you in preparing for your assessment.

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-A
LEARNER GUIDE
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Module A: 0713001135 Repair / Replace allied parts of Machine (Motor)

Objective: This Modulecovers the knowledge & skills required to Repair / replace allied parts of machine (Motor) through Prepare for work, Replace Bearing , Replace Bush , Replace Carbon Brushes , Repair/Replace Commutator , Check Rotor Shaft , Repair/Replace Centrifugal Switch of Motor, Replace Capacitor of Motor , Repair/Replace Terminal plate of Motor ,

Duration: 120 Hours **Theory: 24 Hours** **Practice: 96 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1.Prepare for work to repair / replace allied parts of machine (Motor)	**The trainee will be able to:** • Identify the required PPE's • Collect the required PPE's • Identify the required tools and equipment • Collect the required tools and equipment • Ensure functional condition of PPE's/Tools and equipment • Ensure safe working conditions ➢ Clear Passage ➢ Cleanliness ➢ Adequate light ➢ Ventilation	• Recognition of required Tools, Equipment and PPEs to repair / replace allied parts of machine (Motor) • Importance of functional conditions of required Tools, Equipment and PPEs and their use • Importance of safe working condition regarding ➢ Clear passage ➢ Cleanliness ➢ Adequate light ➢ Ventilation	**Tools** • Spanner Set Screw Driver Set • Allen key Set • Clamp Meter **Consumables Items** • Hand Gloves • Safety Shoes • Safety Goggles
LU2. Replace Bearing	**The trainee will be able to:** • Wear the required	• Demonstration regarding selection & use of required	**Tools** • Screw driver set

	PPE's • Pick the required tools and equipment • Remove the faulty bearing • Collect the relevant number bearing from store • Replace the bearing • Update record	Tools, equipment &PPEs • Describe procedure for selection of right size of bearing. • Describe techniques of replacing faulty bearing. • State method of updating the record.	• Spanner set • Combination plier • Ellen key set • Outside calliper • Inside calliper • Vernier calliper • Bearing puller • Magnifier glass **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Bearing
LU3. Replace Bush	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment • Remove the faulty bush • Collect the relevant size of bush from store • Replace the bush • Update record	• Demonstration regarding selection & use of required Tools, equipment &PPEs • Describe procedure for selection of right size of bush. • Describe techniques of replacing faulty bush. • State method of updating the record.	**Tools** • Screw driver set • Spanner set • Combination plier • Allen key set • Outside calliper • Inside calliper • Vernier calliper • Hammer • Bush Remover Steel Rod **Consumable Material**

			• Lead Pencil • Eraser • Paper / • Inventory register • Bush
LU4. Replace Carbon Brushes	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment • Remove the faulty carbon brush • Collect the relevant size and material of carbon brush from store • Replace the carbon brush • Update record	• Demonstration regarding selection & use of required Tools, equipment &PPEs • Describe method of inspection of carbon brush • Describe procedure for selection of right size of carbon brush. • Describe techniques of replacing faulty carbon brush. • State method of updating the record.	**Tools** • Screw driver set • Spanner set • Combination plier • Allen key set • Long nose plier • Curved nose plier • Magnifier glass • Tweezers **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Sand paper zero size • Carbon Brush
LU5. Repair/Replace Commutator/Slip-	**The trainee will be able to:** • Wear the required PPE's	• Demonstration regarding selection & use of required Tools, equipment &PPEs	**Tools** • Screw driver set • Spanner set

rings	• Pick the required tools and equipment • Check smoothness of the surface of the commutator /slip rings • Perform required surfacing of commutato r/slip rings • Perform undercutting of mica between segments of commutator with hacksaw blade • Perform cleaning of commutator /slip rings • Remove short circuited commutator /slip rings from the motor shaft • Collect the relevant size of commutator /slip ring from store • Replace the commutator /slip rings • Update record	• Describe procedure for checking / inspection of commutator / slipring • Describe techniques / procedure for repairing of commutator /sliprings: ➢ Cleaning ➢ Surfacing ➢ Under cutting Mica • Describe techniques / procedure for replacement of commutator / sliprings • State method of updating the record.	• Combination plier • Allen key set • Outside calliper • Inside calliper • Vernier calliper • Bearing puller • Magnifier glass • Lathe Machine • Hacksaw • Soldering Iron • Soldering Gun • Heat Gun **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Solder wire • Soldering flux • Sand Paper • Shrinkable sleeves • Commutator • Slipring
LU6. Check Rotor & its Shaft	**The trainee will be able to:** • Wear the required PPE’s	• Demonstration regarding selection & use of required Tools, equipment &PPEs	**Tools** • Screw driver set

	• Pick the required tools and equipment • Check smoothness of the surface of the rotor shaft • Check size of shaft according to inner diameter of bearing • Perform welding of shaft for sizing if required • Perform surfacing of rotor shaft to acquire correct bearing size • Check balance of rotor shaft • Perform balancing of rotor shaft if required • Perform cleaning of rotor shaft • Update record	• Describe procedure for checking of rotor bars / rings ➢ Short Circuit ➢ Open Circuit ➢ Damaged bars • Describe procedure for checking / inspection of rotor shaft: ➢ Smoothness of surface ➢ Size of shaft according to inner diameter of bearing • Describe techniques / procedure for welding and surfacing of shaft to acquire correct size of bearing • Describe techniques / procedure for balancing of rotor shaft • State method of updating the record.	• Spanner set • Combination plier • Allen key set • Outside calliper • Inside calliper • Vernier calliper • Bearing puller • Magnifier glass • Lathe Machine • Welding Plant • Growler **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Welding Rod • Sand Paper • Cotton waste • Kerosene oil • Cleaning brush • Grease
LU7. Repair/Replace Centrifugal Switch (Clutch) of Motor	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment	• Demonstration regarding selection & use of required Tools, equipment &PPEs • State centrifugal switch & describe procedure for	**Tools** • Screw driver set • Spanner set • Combination

	• Check working of centrifugal switch • Set working of centrifugal switch • Check contact points of centrifugal switch • Perform surfacing of contact points of centrifugal switch • Perform cleaning of contact points of centrifugal switch • Update record	checking / inspection of centrifugal switch • Describe techniques / procedure for surfacing of contacts of centrifugal switch • Describe techniques / procedure for replacement of centrifugal switch • State method of updating the record.	plier • Allen key set • Outside calliper • Inside calliper • Vernier calliper • Bearing puller • Magnifier glass • Hacksaw • File **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Sand Paper • Centrifugal switch
LU8. Replace Capacitor of Motor	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment • Check the capacitor • Select the required capacitor size. • Collect the capacitor from main store. • Replace the faulty	• Demonstration regarding selection & use of required Tools, equipment &PPEs • Define capacitor & describe techniques / procedure for checking of capacitor • Describe techniques / procedure for replacement of capacitor • State method of updating the record	**Tools** • Screw driver set • Spanner set • Combination plier • Allen key set • Magnifier glass • Series board • LCR meter **Consumable Material** • Lead Pencil

	capacitor • Update record		• Eraser • Paper / • Inventory register • Capacitor
LU9. Repair/Replace terminals of Motor	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment • Perform physical Checking of the terminal plate and terminals of motor • Perform cleaning of terminals and terminal plate to remove carbon dust • Check fixing of terminal plate • Check the terminal linking strips • Repair**/**Replace the faulty part • Update record	• Demonstration regarding selection & use of required Tools, equipment &PPEs • Describe techniques / procedure for checking of terminal plate and terminals of motor • Describe techniques / procedure for repair of terminal plate / terminals of motor: ➢ Cleaning ➢ Surfacing ➢ Linking strips • Describe techniques / procedure for replacement of terminal plate / terminals of motor • State method of updating the record	**Tools** • Screw driver set • Spanner set • Combination plier • Allen key set • Series Test board • Thimble press • Half Round File **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Terminal Plate • Terminal nut & bolts • Linking strip • Sand paper • Thimbles

LU1.Prepare for work to repair / replace allied parts of machine (Motor)

- Recognition of required Tools, Equipment and PPEs to repair / replace allied parts of machine (Motor)
- Importance of functional conditions of required Tools, Equipment and PPEs and their use
- Importance of safe working condition regarding
  - Clear passage
  - Cleanliness
  - Adequate light
  - Ventilation

LU2. Replace Bearing

- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Describe procedure for selection of right size of bearing.**

Visual Determination

Step 1

Clean the old bearing with a rag so that there is no grease on the surface.

Step 2

Look closely at the bearing for its part number. It is typically engraved into a flat section of the metal surface. Two common bearing part numbers are L44649 and L44643.

Take this part number to a parts supplier to get the correct replacement bearings.

Measurement Determination

Step 1

Clean the trailer's spindle with a rag to remove any grease from its surface.

Step 2

Determine the location of the inner bearing on the spindle, the smooth metal surface closest to the middle of the trailer. Measure the width of the spindle in this location with a digital caliper. Close the caliper arms around the spindle and

read the measurement on its display.

☑ **Describe techniques of replacing faulty bearing.**

Electric motor bearings enable the armature inside the motor casing to rotate smoothly. Because the bearings are continuously in contact with the armature spindle they need replacing every so often.

Step 1

Make sure that the electric motor is disconnected from the power supply before you replace the bearings. Locate the screws or bolts around the edge of the motor that keep the two halves of the casing together. Expect to find four or six screws or bolts.

Step 2

Remove the screws or bolts using a screwdriver or wrench. Put the screws or bolts somewhere safe.

Step 3

Use a flat head screwdriver and gently pry the two halves of the motor casing apart. Lift off the top half of the motor casing and lay it next to the bottom half. You can't separate the two halves completely, because there is internal wiring connecting the halves.

Step 4

Hold one end of the armature using one hand and hold the other end with your other hand. Lift the armature directly upward and put it to one side. The armature is the central spindle that has wire winding around the central part. As you lift the armature upward, expect the brushes that touch the commutator at the front of the armature to spring together.

Step 5

Locate the bearings on the front and back of the two halves of the motor casing. There are a total of four bearings. Use a small flat head screwdriver and gently pry out the bearings. Be careful not to scratch the area where they are seated.

Step 6

Wipe the sleeves where the bearings fit using a clean dry cloth. Rub the sleeves using a small amount of engine oil. Wipe off any excess. The oil makes it easier to fit the new bearings.

Step 7

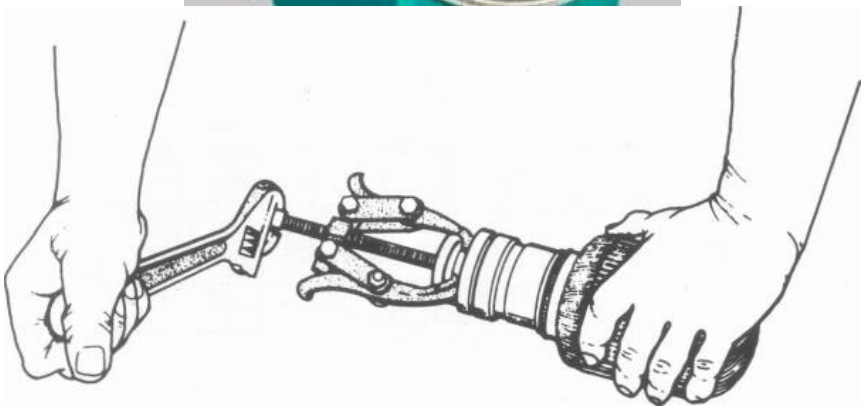
Put the new bearings into the sleeves on the motor casing. Gently push them into place until they are seated tightly.

Step 8

Push the two motor brushes apart. Use your fingers to do this and then replace the armature onto the bottom half of the motor casing. As the armature sits on the bearings, release the brushes so they connect with the commutator.

Step 9

Rotate the armature around carefully so it beds in the lower brushes. Replace the top half of the motor casing. Replace the screws or bolts and tighten them. Rotate the armature several times using your fingers. This beds in all the brushes. Reconnect the electricity supply. Turn on the electric motor.



State method of updating the record.

Update the record regarding repair / replacement of bearing, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of bearing in history sheet of machine.

LU3. Replace Bush

- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Describe procedure for selection of right size of bush.**

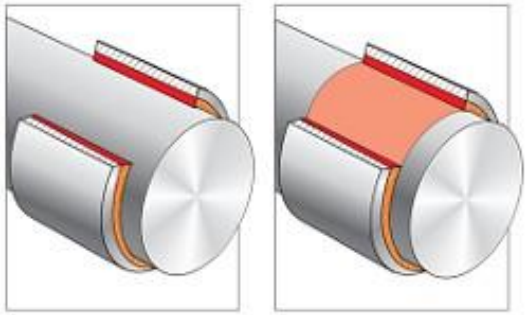
Bushings, also known as “Plain Bearings” or "Sleeve Bearings," are designed for use in numerous applications and offer features and benefits unavailable with many rolling-element bearings. Bushings (plain bearings) are distinguished from rolling-element bearings primarily by the fact that they consist of only one part. That one part may be built up of different

materials, layered and combined into a load carrying system. Depending on the application, bushings are available for operation with supplemental lubrication or to run “dry”, with no additional lubrication. Bushings are available impregnated with lubricant, with lubricant “plug” inserts, or with inherently low coefficients of friction. Bushing materials include cast or machined metals, stabilized polymers (“plastics”), fiber-wound composites, and combinations of different types of materials. Selecting the right bushing for each project requires detailed knowledge of the application requirements and experience with bushing technology. AST’s bearing experts are available to help with advice and guidance to make the selection process as easy as possible.

Selection of Bush:

Selection of correct bushing can be made to replace it with correct type and size. Size is measured by taking its length, outer and inner diameters. Shape is also a key factor to be considered in selection of bush for replacement. Below types of bushes are given in detail.

The Self-Lubricating Bushing Concept:



Self-lubricating bushings are used where the bearing must operate without lubricant or with marginal lubricant. Our focus is on ensuring that the bearing gives the best performance and the longest life under various conditions. The working principle of self-lubricating bearings is that, during the initial run-in period of the bearing, there will be a solid lubricating film created by the transfer of a small amount of material from the bearing layer. This film directly contacts the moving parts, protecting and lubricating the mating components and extending the service life of the bearing.

The Advantages of Self-Lubricating Bushings:

- Elimination Of Oil Holes And Grooves - Cost for machining oil holes and oil grooves is unnecessary. Self-lubricating eliminates the need for the extra oiling system.
- Reduction Of The Machinery Running Cost - With maintenance free features, the lubricant oil is dramatically reduced; machinery running cost will also be decreased.
- Maintenance Free Operation - Self-lubricating bearings solve the problem of oiling operation and oiling devices, also saving bearing maintenance costs.
- Simplified Mechanical Design And Manufacture - With above advantages, thin wall thickness, higher load, and excellent wear resistance, mechanical designs can be simplified and made more economical.

- The Environment Is Protected - The self-lubricating bearing materials work without oil and meet the ROHS directive.

Metal-Polymer Composite Bushings (Plain Bearings)

AST has successfully supplied PTFE and thermoplastic metal-polymer bushings to the market since the very beginning. They consist of metal backing bonded to a porous bronze sintered layer with a PTFE or thermoplastic based Polymer bearing lining layer. The metal backing provides mechanical strength while the bronze sintered layer provides a strong mechanical bond between the backing and the bearing lining. The PTFE based polymer offers exceptionally low friction even under dry conditions and the thermoplastic based polymer is designed for operating with marginal lubrication. This structure promotes dimensional stability and improves thermal conductivity.

Bi-metallic Composite Bushings

Bi-metallic material shells cover self-lubricated AST850 series and pre-lubricated AST800 series bushings. The AST850 series combines a bi-metallic shell backed with a sintered bronze alloy which is uniformly dispersed with solid lubricants. This bearing layer offers low friction and good performance under limited lubrication. The AST800 series has a steel shell backed with a lead bronze lining material for oil/grease lubricated applications. These bearing structures provide high load capacity with good fatigue properties. Tighter tolerance control can be achieved by re-machining the assembled bearing.

Bronze Wrapped Bushings

These bushings are wrapped from a cold formed homogenous bronze (CuSn8) with exceptional material properties. Depending on the lubrication conditions, the bearing can be provided with diamond shaped lubricant indents (for grease) or through holes (for grease or oil). With this design, a lubricant film rapidly builds up during the initial run-in period of the mating parts and thereafter running friction is considerably reduced. The AST090G material has graphite embedded into the diamond indentations to provide good lubrication conditions on start-up, even when operated with no added lubrication. This bearing design provides high load carrying capacity, good fatigue properties, dimensional stability, and improved thermal conductivity. Tighter tolerance control can be achieved by re-machining the assembled bearing.

Metallic Self-lubricating Bushings

Metallic bushing materials consist of high strength metal backing embedded with solid lubricants. The metal provides

high load capacity and the solid lubricants provide low friction during operation. These bushings are precision machined with tighter tolerance to provide accurate fits after installation. This bearing design provides high load carrying capacity, good fatigue properties, dimensional stability, and improved thermal conductivity. Tighter tolerance control can be achieved by re-machining the assembled bearing.

Filament Wound Plastic Self-lubricating Bushings

AST CR series composite bushings consist of a continuous-wound glass fiber encapsulated in a high temperature epoxy resin with a variety of low friction wear resistant bearing linings. The reinforced composite structure enables the bearing to support high static and dynamic loads while providing excellent wear resistance. This bearing can be used for extremely high impact load applications and in highly corrosive media.

Injection Molded Plastic Self-lubricating Bushings

AST-EPB plastic bushings are made of a variety of resins combined with reinforcing fibers and solid lubricants to provide excellent wear resistance and low friction in both dry and lubricated operating conditions over a wide range of applications. EPB material is an economic solution for mass production designs.

Describe techniques of replacing faulty bush.

When bushes are worn the play between shaft and inner diameter of bush is increased, rotor does not move freely and armature stuff with stator due to magnetic effect of current, so it necessary to replace it with new one of same size, type and material. To replace faulty bush following procedure should be adopted.

1- Dis-attach the motor end plates
2- Remove the bushing from housing
3- Clean the faulty bush
4- Take size
5- Arrange new one
6- Place new bush in housing
7- Oil the bush
8- Attach the motor end plates

https://www.youtube.com/watch?v=NLOsN30TD3o

You can see the video of changing bushing from above website

State method of updating the record.

Update the record regarding repair / replacement of bushing, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of bushing in history sheet of machine.

LU4. Replace Carbon Brushes

- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Describe method of inspection of carbon brush**

Carbon Brush

A carbon brush, also known as a motor brush, is the small part of the motor that conducts electrical current between the stationary wires (stator) and the rotating wires (rotor) of a motor or generator. The brush is typically made up of one or more carbon blocks and can come with one or more shunts or terminals.

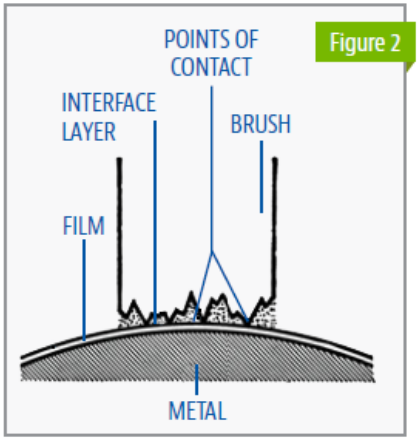
A motor generally contains more than one carbon brush to conduct electrical current. The brushes are categorized into five brush-grade families, each of which is suited for different kinds of motors and applications.

A carbon brush has three operating parameters: mechanical, electrical, and physical/chemical.

Mechanical

A slip ring or commutator is attached to the rotating shaft. A spring is used to push the brush into the slip ring or commutator to maintain contact. The surface of the slip ring or commutator should not be too smooth/glossy or too rough in order to ensure good brush contact and performance.

Electrical

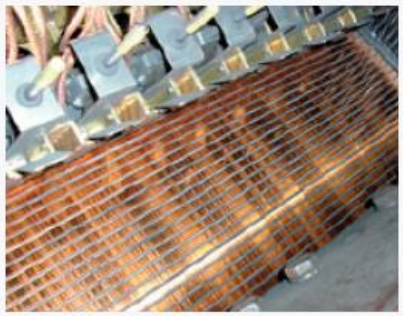


Electrical current is transmitted from the rotating shaft via contact with the carbon brush. Very small areas of the brush,

called contact spots, contact the surface of the slip ring or commutator. The contact spots should be evenly distributed on the surface of the brush to maintain brush balance and avoid damage to the commutator / slip ring surface.
Carbon brushes with high resistivity work best, because this helps prevents arcing at the interface between the brush and commutator / slip ring. It is also important to maintain a proper power density for DC motors to operate at peak performance which often requires removing brushes. Calculations for power density should be performed and brush density optimized if your application changes. Brushes should not be assumed to be missing if you find a DC motor operating with brushes removed.

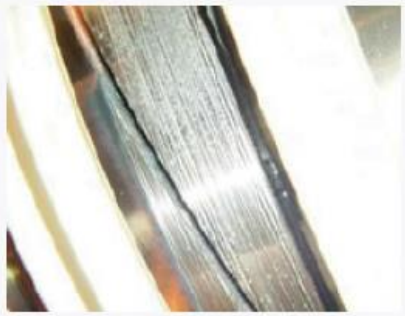
Physical/Chemical

This operating parameter refers to the operating environment of the carbon brush, rather than to the brush itself, which can have a strong effect on carbon brush performance.
For example, a certain level of air humidity is needed for the commutator/slip ring film to form properly. Thus, if air is too dry, such as in desert, arctic, or aerospace conditions, special brush treatments are recommended. Treatments are also available for brushes exposed to corrosive vapors and gases (which can occur, for example, in the presence of silicone or other adhesives). Finally, oils, hydrocarbons, and dust can deteriorate a carbon brush and should be avoided.



P1

P2



P2a

P1 is a good example of streaky film, which contains lines of varying widths, alternating light and dark, without copper wear. Frequent causes include excessive humidity, aggressive gases or oil vapors in the atmosphere, underloaded carbon brushes.

P2 and P2a depict raw grooved film. This is a result of excessive exposure to humidity, aggressive gases or oil vapors in the atmosphere, for long periods of time. Additionally, the carbon brush grade may not be suitable.

Carbon Brush Inspection

There are several ways to check for issues and to be sure your carbon brush — and your motor — are working properly. One of the first things to look at is carbon brush stability. Check the clearance between brush holders and the brush to ensure it is stable and slides properly. It's also important to check the distance between the brush holder and commutator slip ring to ensure the brush holder is adjusted correctly and at the proper angle.

It is important to also check for signs of commutator wear and for the presence of copper dust. Dust leads to high brush wear, machine pollution, grooving of commutator / slip rings and brush side gulling. The best way to prevent this is with regular motor cleaning to ensure air filters provide clean air to the motor.

Describe procedure for selection of right size of carbon brush.

Carbon brush size is taken by measuring its length, width & height. The size can be measured with steel rule or Vernier calliper. Video of taking size can be seen by using the following website address.

https://www.youtube.com/watch?v=F_Hm7-hOh_U

- **Describe techniques of replacing faulty carbon brush.**

Brushes can be checked visually or tested with a continuity tester. Here's how:

Step 1: To sight-check the carbon brushes, remove the screws that hold the brushes and brush springs into the brush holders at the sides of the commutator. The screws will pop out of the screw holes; turn the motor over to tap out the brushes. The ends of the brushes should be curved to fit the commutator; if they're worn down, new brushes are needed.

Step 2: To check carbon brushes with a continuity tester, remove the motor lead wires from the circuit. Tag the wires as you disconnect them so that you'll be able to reconnect them properly. Hook the tester clip to one motor lead and touch the probe to the other lead; the tester should light or buzz. Slowly rotate the motor shaft, keeping the tester in position. If the tester doesn't light or buzz, or if it flickers or stutters when you turn the motor shaft, the brushes should be replaced. If the springs behind the brushes are damaged, they should be replaced as well.

Step 3: Replace worn carbon brushes and damaged springs with new ones made specifically for the motor. The model information (number and make) is stamped on a metal plate fastened to the motor, or embossed on the metal housing of the motor. If you can't find the model information, take the worn brushes and springs with you to an appliance-parts store to make sure you get the right kind. Insert the new springs and brushes in the brush holders, replace the brush assemblies, and secure the new brushes with the mounting screws that held the old brushes.

Don't attempt other repairs to a universal motor. If a serious malfunction occurs, buy a new motor or take the faulty motor to a professional for repairs. Most large universal motors are fastened to plate-type mountings. To remove the motor, disconnect the wires and remove the holding bolts and any belts that are present. If the faulty motor is in a small appliance, take the entire appliance to the repair shop. It may sometimes be less expensive to buy a new appliance than to have the old one repaired. You can see the video using the following website address

https://www.youtube.com/watch?v=cCB0WgpV8Iw

Most electrical appliances such as power tools and Kitchen Aids have motors having carbon brushes, and the most common thing to stop a motor from working is worn carbon brushes. Method of replacement is shown below.

Drag motor onto your work space and start looking for the 2 carbon brushes. I'm pointing to where the 2 carbon brushes are.	
The actual carbon brush is held in place by a small brass clip which needs to be wiggled out of its spot.	

	Then just give a little pull to pull the old brush out. Make sure you pay attention to what direction the carbon brush came out! It has a beveled edge and the new one has to go in the same way the old one came out, otherwise the brushes will be rubbing on the (we don't care) commutator the wrong way and don't work.		
	As a reminder, this is the old brush beside a new brush. You can see how worn down the old one is. No wonder it didn't work anymore.		
	Put the new carbon brush in. Just feed it into the hole you took the one out of, making sure to put it in the same way. You can see I drew a picture with a Sharpie on my motor so I wouldn't forget which direction to put it in.		

If had trouble getting it all the way down then just use a bamboo skewer to coax it down.	
Squishing the springy coil down takes some patience and fiddling. Just keep at it and it'll all go down. Then insert the clip into the slot. Reattach the electrical clip.	

State method of updating the record.

Update the record regarding repair / replacement of carbon brush, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of carbon brush in history sheet of machine.

LU5. Repair / Replace Commutator / slip-ring

- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Describe procedure for checking / inspection of commutator / slipring**

The commutator can be defined as is an electrical rotating switch in particular type of generators as well as motors. This

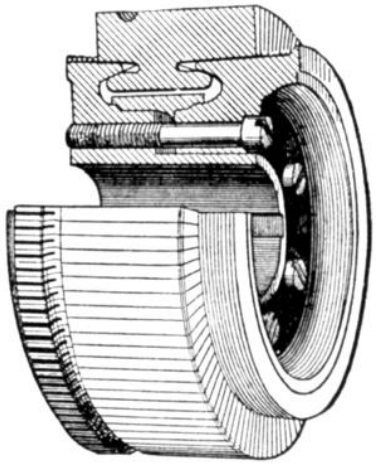
is mainly used to overturn the direction of current among the external circuit & rotor. It comprises a cylinder with numerous metal contact segments lying on the revolving armature of the machine. The brushes or electrical contacts are made with a carbon press material next to the commutator, designing sliding contact by consecutive segments of the commutator while it revolves. The armature windings are allied to the segments of the commutator.

The applications of commutator include DC **(**direct current**)** machines like DC generators, numerous DC motors, as well as universal motors. In a DC motor, the commutator provides electric current to the windings. By changing the direction of current within the revolving windings every half turn, a torque (steady revolving force) will be produced.

Commutator Construction and Working

The construction and working of a commutator are, a commutator can be built with a set of contact bars that are set toward the revolving shaft of a DC machine, and allied to the armature windings. When the shaft turns, the commutator will reverse the current flow within a winding. For a particular armature winding, once the shaft has completed the one-half turn, then the winding will be connected so that current supplies through it in the reverse of the first direction.

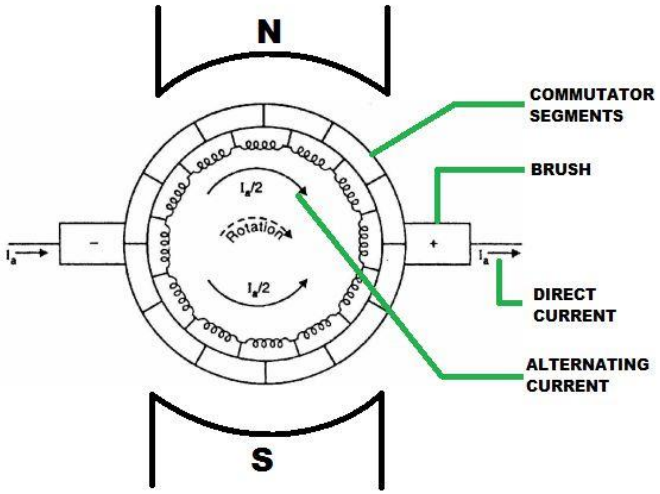
In a DC motor, the armature current causes the set magnetic field to use a rotating force, otherwise a torque over the winding for making it revolve. In a DC generator, the mechanical torque can be applied in the direction of the shaft to maintain the armature winding motion via the stationary magnetic field, stimulating a current within the winding. In these two cases, Sometimes, the commutator will reverse the direction of current flow throughout the winding so that the flow of current within the circuit which is external to the machine maintains in only one direction.



Commutator Construction

Function of Commutator in DC Machines

The role of the commutator in DC machines is like a reversing switch, and its working in the motor, as well as a generator, is discussed below.



Commutator in DC Machines

Commutator in DC Motor

The commutator in case of a DC motor, it reverses the flow of current which is accessible from a DC source at the exact time while the armatures coil crosses the magnetic unbiased axis. This is essential to keep a uni-directional torque. Therefore, the commutator will change the direct current (DC) into alternating current (AC).

Commutator in DC Generator

The commutator in case of a DC generator, the induced e.m.f. within the armature coil will change in nature. Consequently, the flow of current in the armature coil will also be changed. This current will be reversed by the commutator at the exact time while the armatures coil crosses the magnetic unbiased axis. So, the load which is external to the generator will get a uni-directional current otherwise DC (direct current).

Slip Ring Commutator

A slip ring commutator is an electro-mechanical device, used to allow the power transmission as well as electrical signals from an immobile to a revolving structure. This can be utilized in any kind of electro-mechanical system that needs revolution while power transmitting. It can recover mechanical act, make simpler system operation & get rid of damage-prone wires hanging from variable joints. A slip ring commutator is a technique of building an electrical connection throughout a rotating assembly. Properly, it is an electric communication device that permits the flow of energy among two electrical rotating elements in a motor.

Slip Ring Commutator Construction

The slip ring commutator construction is, consists of immobile graphite otherwise brush which is known as metal contact

which wipes on the exterior diameter of a revolving metal ring.
When the metal ring twists, the flow of electric current otherwise signal is performed through the immobile brush toward the metal ring for making the connection. An extra ring or brush gatherings are stack along with the revolving axis if more than a single electrical circuit is required.
Both the brushes otherwise the rings are motionless, another component will rotate. This easy design has been utilized for decades like a basic method of passing current into a rotating device.

Types of Slip Rings

Slip rings are available in various sizes as well as types. This will allow for infinite turns of the allied object, while a slack-cable cannot be turned many times before it will not pass. The slip rings are classified into three types such as Mercury-wetted, Pancake, and Wireless.

Other Names and Uses of Commutator

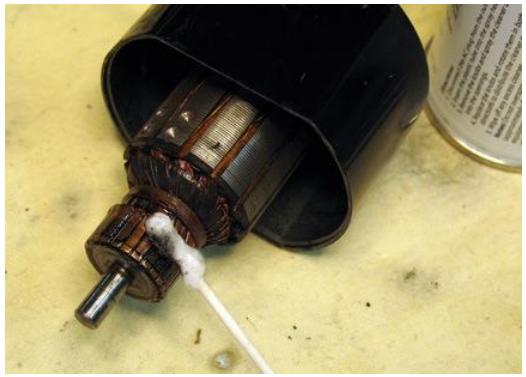
Other names of slip ring mainly include rotary electrical contact ring, collector ring, & electrical ring. Based on the application, it can be named as the commutator, but these are fairly different & are particularly used for DC motors as well as generators.
As commutator is sectioned, these are continuous, and the names are not identical. Rotary transformers are frequently used in its place of slip rings in the environments like high-speed, otherwise low-friction.
This can be used to act concurrently in a rotary union by the device, which is normally called as a rotary joint. These rings perform the similar for electrical power as well as a signal that rotary unions perform for fluid media. They are frequently incorporated into rotary unions for transmitting power & data from revolving machinery within conjunction by the media that the revolving union supplies.
This can be used to act concurrently in a rotary union by the device, which is normally called as a rotary joint. These rings perform the similar for electrical power as well as a signal that rotary unions perform for fluid media. They are frequently incorporated into rotary unions for transmitting power & data from revolving machinery within conjunction by the media that the revolving union supplies.

Checking:

Observe the condition of commutator and that:
Is its surface is smooth?
Is its color is bright?
Is carbon is deposited on its surface?
Is mica needs to be under cut?
On the bases of this physical inspection you can decide about cleaning, surfacing or under cutting mica for getting repair.

Cleaning:

This process is performed when the surface of commutator blackened due to carbon deposit. Clean the surface with cotton waste, use kerosene oil to wash it or use electronics cleaner on a Q-tip for preliminary cleaning, it gets a lot of the carbon and grime off easily.



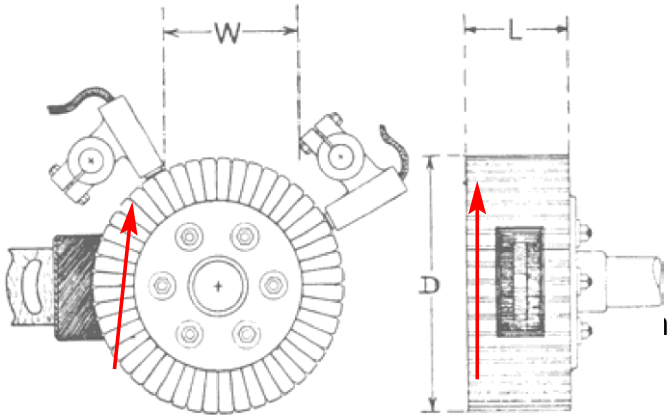
The best way to clean a commutator so as to maintain the curve is to remove it from the motor housing and chuck it in a drill, then use a strip of polishing paper held around it while you rotate the commutator.

Surfacing

When the surface of commutator has groves on it and it is not in smooth form the it is required to be surfaced. To surface its face we can do it with following two methods.

1- Using commutator stone:

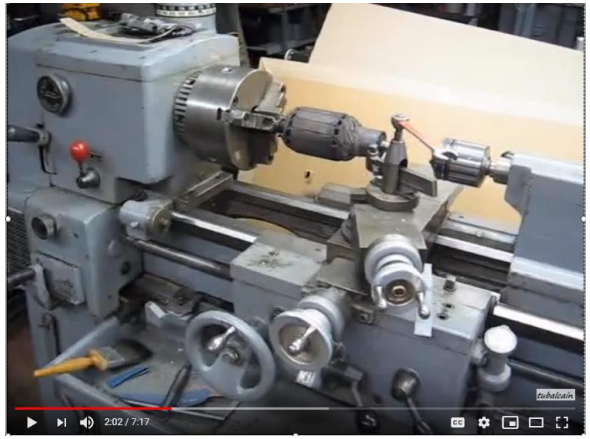
If greaseoroilispresent,wipeorsandpaperthecommutatorthoroughlybeforeapplyingthestone. Run the machine at full speed. Position the Commutator stone so that the top surface of the commutator moves away from stone. As shown. Do not rock the stone; hold it firmly in order to get a true arc as quickly as possible. Applywithsufficientpressuretogetrapidcutting.Ifthestonewearsfasterononesidethanontheother,itisbecause thepressureisnotappliedperpendicularly.Thismaybecorrectedbyturningthestonethreeorfourtimesuntilthefull face has beenobtained.Duringgrinding,movethestoneslowlyfromsidetoside.Thiswillpreventridgesinthecommutatorfromwearinggrooves inthestone.Largestoneswhicharedifficulttomovewhilegrindingmaybeheldinoneplaceforafewseconds,then lifted,movedabout1/4inch,appliedagainforafewseconds,movedagain,andsoonuntilthecommutatoristrue.Save from 75% to 95% of the cost of turning a commutator. Save from 80% to 99% of the time required to remove an armature and turn the commutator in a lathe.



ı by arrow.

2. **Turning on lathe:**

- First make sure the armature shaft is straight and in good condition. When overhauling an armature in the shop, true the commutator by supporting it in a lathe, turning, and cutting.
- With a diamond point tool, cut only enough material to the surface with a minimum amount of wear to sufficiently so that the cuts will overlap and not leave a rough thread on the commutator.
- The proper cutting speed is about 100 feet per minute, and the feed should be about 0.10 inch per revolution.
- The depth of cut should not be more than 0.010 inch. When there are noticeable commutator scratches or roughness, use very fine sandpaper (no coarser than No. 0000) to remove them.
- After turning the commutator, finish it with a hand stone and sandpaper.



To see turning process on lath please open the given website link
https://www.youtube.com/watch?v=VHjGc_qjNcE

Under cutting Mica

Commutator undercutting is performed to undercut the mica separating the copper segments so that the carbon brushes will wear evenly. Mica is hard and does not wear down evenly with the copper segments. Over the lifetime of a DC motor, the commutator will be undercut as part of a prevent maintenance program to eliminate arcing and extend the brush life.

Under cutting of mica can be performed with hacksaw blade, under cutting mica tool or automated under cutting. In picture below process of under cutting mica with mica under cutting tool is illustrated.

Automated undercutting provides for a quicker and more accurate job. The floating head and power feed ensures the cutting wheel follows the mica and minimizes burrs. A de-burring attachment removes burrs and rounds the corners of the newly cut bar.

Describe techniques / procedure for replacement of commutator / sliprings

Commutator is not generic replacement parts which means that a replacement will likely have to be for that specific motor and that makes the likely hood of finding one pretty slim. In figure below the condition of commutator demands that it should be replaced with new one.

A good motor shop should be able to perform the replacement. Basically, it involves;

- Cutting the bars from the risers to disconnect its connections
- Pushing the old commutator out with puller
- Pushing new commutator in manually or hydraulically

- Cementing it with epoxy
- Re-brazing its connection
- Be sure that in addition to the final diamond turn, the micas are undercut to prevent carbon tracking

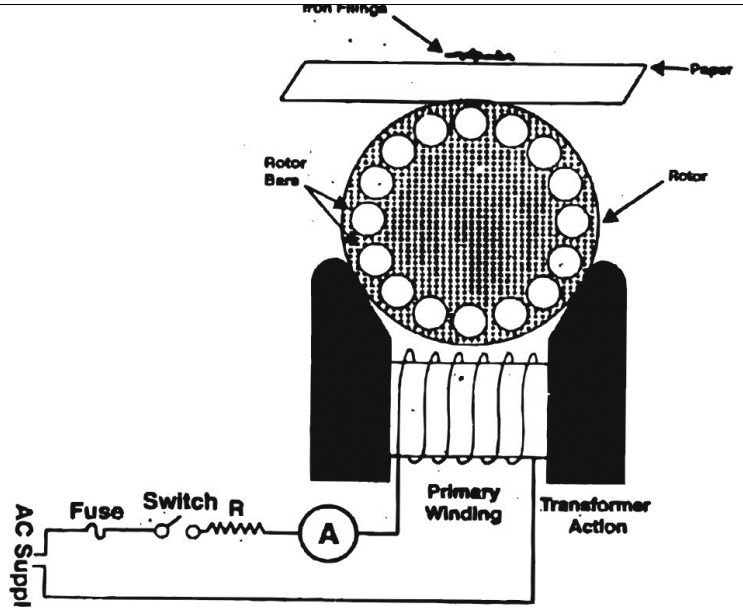
State method of updating the record.

Update the record regarding repair / replacement of commutator, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of commutator in history sheet of machine.

LU6. Check Rotor & its Shaft

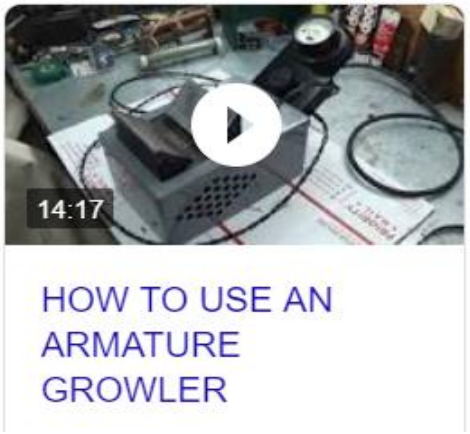
- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Describe procedure for checking of rotor bars / rings**
  - **Short Circuit**
  - **Open Circuit**
  - **Damaged bars**

Growler is used to test motor armature and rotor. Open circuit, short circuit and insulation test can be performed on growler. Constructional details of growler are shown in figure below.



The alternating magnetic flux set up by the growler passes through the windings of the armature coil, generating an alternating voltage in the coil. A short in the coil creates a closed circuit that will act like the secondary coil of a transformer, with the growler acting like the primary coil. This will induce an alternating current in the shorted armature that will in turn cause an alternating magnetic field to encircle the shorted armature coil. A flat, broad, flexible piece of metal containing iron is used to detect the magnetic field generated by a shorted armature. A hacksaw blade is commonly used as a feeler. The alternating magnetic field induced by a shorted armature is strong at the surface of the armature, and when the feeler is lightly touched to the iron core of an armature winding, small currents are induced in the feeler that generate a third alternating magnetic field surrounding the feeler.

With the growler energized, the feeler is moved from slot to slot. When the feeler is moved over a slot containing the shorted coil, the alternating magnetic field will alternately attract and release the feeler, causing it to vibrate in synch with the alternating current. A strong vibration of the feeler accompanied by a growling noise indicated that the coil is shorted.



https://www.youtube.com/watch?v=Lk8UEaEcZME

GROWLER TEST - A growler is an electrical device used for testing insulation of a motor for shorted coils. A growler consists of a coil of wire wrapped around an iron core and connected to a source of alternating current. When placed on the armature or stator core of a motor the growler acts as the primary of a transformer and the armature coils act as the secondary. A "feeler", a thin strip of steel such as a hacksaw blade or metal filings can be used as the short detector. For best results the rotor should be heated.

SINGLE PHASE ROTOR TEST - Single phase power is applied to the motor while the rotor is slowly rotated. Using an analog meter, any fluctuation in amp draw is monitored. Lower or increased stator current is a sign that one or more cracked rotor bars are present. This test is best performed with the rotor heated and while the motor is still intact.

HIGH CURRENT ROTOR TEST - This test is performed by applying high current through the shaft of the rotor thermally scanning the rotor searching for shorted laminations. (Laminations are the steel portions of the stator and rotor consisting of thin lamination sheets stacked together.)

Hot spots can be caused by shorted laminations. This can result in uneven heating of the rotor which then causes the rotor to bow and go out of balance. Stress to the bars and premature bar cracking and fatigue are most often the result. A loose rotor to shaft interference fit can also be detected with this test.

INDUCTION MOTOR CURRENT ANALYSIS (CURRENT SPECTRUM TEST) - This test is considered the most accurate and reliable. It is performed while the motor is under 50 - 100% load. The rotor induces currents back in the stator windings.

These appear as side bands around the supply line frequency (60 HZ) peak, and are a function of the motors number of poles and slip frequency (the difference between synchronous speed and operating speed, at the same frequency, expressed in rpm, or in percentage or ratio of synchronous speed.) An estimate of the number of broken rotor bars can

be determined by comparing the sideband amplitudes.

VIBRATION SPECTRUM ANALYSIS – When you want to detect cracked or loose bars while under load, you can use this test.

Under load, the vibration will modulate at a rate equal to the number of poles times slip frequency. The amplitude of the beat increases with load if there is a cracked rotor bar. This can also cause localized heating of the rotor which causes uneven expansion and rotor bowing.

This result in an unbalance and a strong 1 times running speed vibration as well as the side bands related to slip frequency. Loose rotor bars may give similar symptoms and also will show vibration at rotor bar passing frequencies.

This test will not show up at no load running because a broken rotor bar cannot carry current. When it is in an area of high flux, the magnetic forces on the rotor are unbalanced. Since the current flow through the rotor bar is proportional to slip, at no load when rotor current is low, the bar has virtually no magnetic forces acting on it.

The use of these methods will also provide additional clarity to the vibration data. Very few rotor bar defects lead to catastrophic motor failure.

The presence of broken bars will cause an increase in overall motor losses and a decrease in motor efficiency. The additional heat generated from the added current will also further increase the rate of insulation degradation in the stators.

Describe procedure for checking / inspection of rotor shaft:

- **Smoothness of surface**
- **Size of shaft according to inner diameter of bearing**

Measurement of the inside diameter of the hole and outside diameter of a shaft. Slide calipers (Digital, Dial or Vernier), outside/ inside micrometers, bore gauges and pin gauges are often used for diameter measurement and control in mechanical engineering applications. The selection of the tool depends on the accuracy requirement and the feature to be measured.

Slide Calipers: A tool used to measure the inside and outside distance (diameter) and depth of a feature. Different models exist such as digital, dial and Vernier calipers. Measurement accuracy of a slide caliper generally ranges from +/- 0.001 inch to +/- 0.0015 inch (+/- 0.02 mm to +/- 0.04 mm). These values depend on the quality of caliper and measurement length. Different measuring length options exist but common one is 0 to 6 inches (0 – 150 mm).

Micrometers: An accurate measurement device to measure dimensions of an object. It's also known as micrometer screw gage since there is a calibrated screw exist inside the micrometer. Main types are outside, inside and depth micrometers. Outside micrometers are used to measure diameter and thickness of shafts, wires, plates. Inside micrometers are used to measure diameter of holes. Depth micrometers are used to measure the depths of holes, slots, shoulders. Measurement accuracy of micrometers is in the range +/- 0.00005 inch to +/- 0.001 inch (+/- 0.001 mm to +/- 0.02 mm). Accuracy value depends on the micrometer type, quality of and the measurement range.

Bore Gauge: A tool to measure the bore diameter of cylinders, pipes and bearings. There are different types of bore gauges which can be classified as dial bore gauges and transfer bore gauges. Transfer bore gauges consist of telescopic gauge and small hole gauges. In transfer type bore gauges, there are no scales on the tool. After the measurement with a transfer type bore gauge, the distance between contacts of the gauge are measured with a caliper or micrometer. In case of dial bore gauge, measurement is read from the dial. Different measurement length options exist.

Pin Gauges: These tools are used to check the limits of size of a hole. Pin gauges are precision machined metal plugs and there are different tolerance classes. Pins can be either “plus” or “minus” tolerance pins. “Minus” gauge pins are most commonly used. GO/NOGO measurement shall be done with pin gauges to check upper and lower limits of a hole.

Describe techniques / procedure for welding and surfacing of shaft to acquire correct size of bearing

Vibration can be destructive if a motor drive shaft, for instance, has loose bearings or is loosely attached to its mounts. The effects of vibration can be severe, and if left unchecked can accelerate rates of wear and lead to costly equipment failure and downtime.

Mechanical looseness occurs when there is excessive clearance between parts. Such looseness may or may not be caused by the underlying vibration. Whatever its cause, any amount of looseness will allow tiny vibrations to cause further wear and fatigue in equipment mounts, bearings, and other components. Looseness can occur in several places.

- Rotating looseness is caused by excessive clearance between rotating and stationary elements of the machine, such as in a bearing.
- Non-rotating looseness happens between two normally stationary parts, such as a foot and a foundation, or a bearing housing and a machine.

As with all other sources of machine vibration, it is important to know how to identify looseness and resolve the issue to avoid losing money from destroyed equipment or downtime. A vibration tester can determine whether a rotating machine is experiencing looseness. The Fluke 810 Handheld Vibration Tester can be used in a preventive maintenance program as an indicator of machine condition that not only includes looseness but also unbalance, shaft misalignment and bearing failures.

To accrue correct size of motor shaft for proper fitting of bearing, you have to add a layer of metal by welding at the shaft of motor at the place meant for bearing housing, then surfacing on lathe machine and cutting off the excess material. Bearing should be fitted not too loose and not too tight.

Describe techniques / procedure for balancing of rotor shaft

A balancing machine measures the level of unbalance within parts through vibration analysis. Balancing machines have two pedestals that sit on top of a supporting platform. The part that needs to be tested is bolted on a platform and rotated with a belt or end driver. While the part is rotating, the balancing machine aims to monitor vibration by detecting vibrations through the machine's sensors. This information is then used to determine how balanced the part is.

There are two types of balancing machines; soft-bearing and hard-bearing.

A long time ago, it was essential for a balancing technician to be able to perform all of the balancing calculations, and human error was a potential contributing factor in all balancing situations. Now, everything is automated. When using balancing soft bearing balancing machines, one simply follows the instructions on the screen, step by step. This steps are as follows:

1. Chose the Rotor Setup,
   Choose the rotor configuration, Spin the rotor and take a measurement reading, then stop the rotor
2. Calibration of the Machine with the Rotor
   The Balancing Instrument will then instruct the user to add a known weight to the first correcting location on the left hand side, enter the illustrated required dimensions, spin up the rotor and take a measurement, stop the rotor, then remove the left hand weight and place it in the right hand correction plane and repeat. Stop the rotor and remove the known weight. The instrument then uses these measurements to calibrate itself.
3. Balancing the Rotor
   The Balancing Instrument now displays both the left and right hand correction amounts and the angular location of the correction weights for the addition or subtraction of material.

To see the video of rotor balancing use website given

http://www.irdbalancing.com/balancing-machines---types%2C-classification%2C-and-methods.html

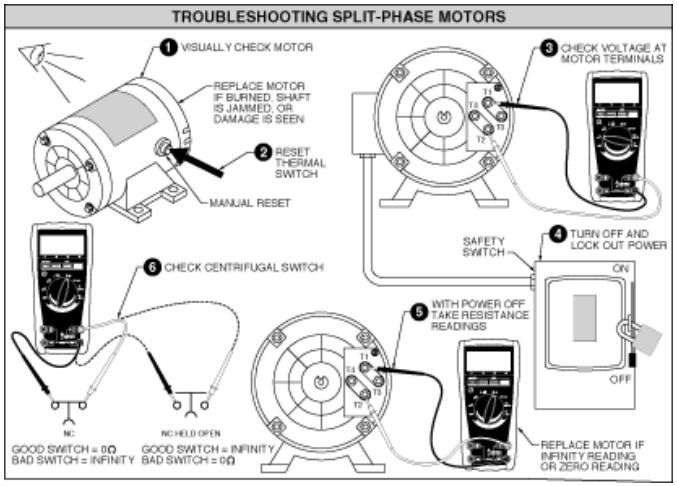
State method of updating the record.

Update the record regarding checking / repair of rotor bars and balancing, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the repair of rotor bars and balancing in history sheet of machine.

LU7. Repair/Replace Centrifugal Switch (Clutch) of Motor

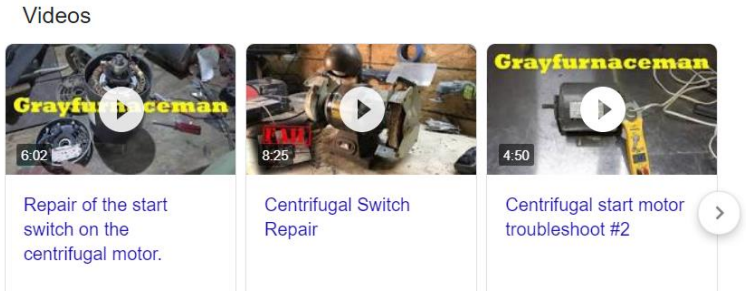
- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **State centrifugal switch & describe procedure for checking / inspection of centrifugal switch**

Centrifugal switch controls the start winding in single-phase electric motors. A centrifugal switch consists of two parts, centrifugal mechanism which rotates on the motor shaft and interacts with fixed stationary switch with electrical contacts which control the start winding circuit.



When checking centrifugal switch you needs to check that;

1. Its contact points are cleaned and free of rust or carbon.
2. Its moving contact is properly greased.
3. Its contacts points are joining with proper pressure.



To see video about working of centrifugal switch use the given website

https://www.youtube.com/watch?v=DQUMSbgivN8

Describe techniques / procedure for surfacing of contacts of centrifugal switch

- De-attach the end plates of motor.
- Visually inspect the centrifugal switch for;
  - ✓ Signs of burning or broken springs.
  - ✓ Signs of carbon, sparking on contacts
- Surface the contacts with file
- Polish contact for final surfacing with sand paper
- Check the switch continuity using an ohmmeter.
- Manually operate the centrifugal switch three four times. Verify its proper working.

Describe techniques / procedure for replacement of centrifugal switch

- De-attach the end plates of motor.
- Visually inspect the centrifugal switch for;
  - ✓ Signs of burning or broken springs.

- ✓ Signs of carbon, sparking on contacts
- ✓ Signs of burning of contacts

- Remove the centrifugal switch
- Fit a new one centrifugal switch
- Check the switch continuity using an ohmmeter.
- Manually operate the centrifugal switch three four times. Verify its proper working.
- **State method of updating the record.**

Update the record regarding repair / replacement of repair / replacement of centrifugal switch, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of centrifugal switch in history sheet of machine.

LU8. Replace Capacitor of Motor

- **Demonstration regarding selection & use of required Tools, equipment &PPEs**
- **Define capacitor & describe techniques / procedure for checking of capacitor**

The capacitor is a component which has the ability or “capacity” to store energy in the form of an electrical charge producing a potential difference (Static Voltage) across its plates, much like a small rechargeable battery. In its basic form, a capacitor consists of two or more parallel conductive (metal) plates which are not connected or touching each other, but is electrically separated either by air or by some form of a good insulating material such as waxed paper, mica, ceramic, plastic or some form of a liquid gel as used in electrolytic capacitors. The insulating layer between capacitors plates is commonly called the Dielectric.

Due to this insulating layer, DC current cannot flow through the capacitor as it blocks it allowing instead a voltage to be present across the plates in the form of an electrical charge.

The conductive metal plates of a capacitor can be square, circular or rectangular, or they can be of a cylindrical or spherical shape with the general shape, size and construction of a parallel plate capacitor depending on its application and voltage rating.

When used in a direct current or DC circuit, a capacitor charges up to its supply voltage but blocks the flow of current through it because the dielectric of a capacitor is non-conductive and basically an insulator. However, when a capacitor is connected to an alternating current or AC circuit, the flow of the current appears to pass straight through the capacitor with little or no resistance.

There are two types of electrical charge, positive charge in the form of Protons and negative charge in the form of

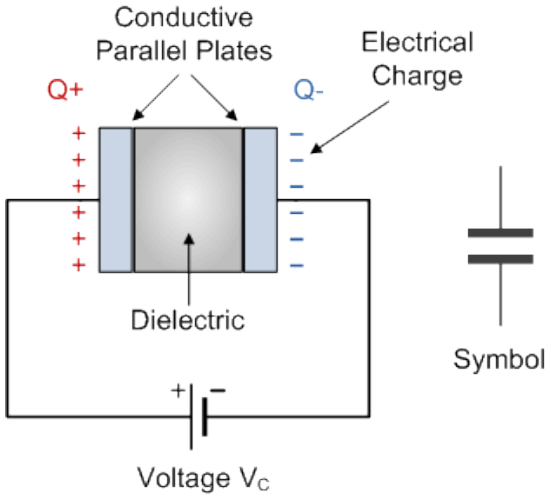
Electrons. When a DC voltage is placed across a capacitor, the positive (+ve) charge quickly accumulates on one plate while a corresponding and opposite negative (-ve) charge accumulates on the other plate. For every particle of +ve charge that arrives at one plate a charge of the same sign will depart from the -ve plate.

Then the plates remain charge neutral and a potential difference due to this charge is established between the two plates. Once the capacitor reaches its steady state condition an electrical current is unable to flow through the capacitor itself and around the circuit due to the insulating properties of the dielectric used to separate the plates.

The flow of electrons onto the plates is known as the capacitors Charging Current which continues to flow until the voltage across both plates (and hence the capacitor) is equal to the applied voltage Vc. At this point the capacitor is said to be “fully charged” with electrons.

The strength or rate of this charging current is at its maximum value when the plates are fully discharged (initial condition) and slowly reduces in value to zero as the plates charge up to a potential difference across the capacitors plates equal to the source voltage.

The amount of potential difference present across the capacitor depends upon how much charge was deposited onto the plates by the work being done by the source voltage and also by how much capacitance the capacitor has.



The parallel plate capacitor is the simplest form of capacitor. It can be constructed using two metal or metalized foil plates at a distance parallel to each other, with its capacitance value in Farads, being fixed by the surface area of the conductive plates and the distance of separation between them. Altering any two of these values alters the value of its capacitance and this forms the basis of operation of the variable capacitors.

Also, because capacitors store the energy of the electrons in the form of an electrical charge on the plates the larger the plates and/or smaller their separation the greater will be the charge that the capacitor holds for any given voltage across its plates. In other words, larger plates, smaller distance, more capacitance.

By applying a voltage to a capacitor and measuring the charge on the plates, the ratio of the charge Q to the voltage V will give the capacitance value of the capacitor and is therefore given as: C = Q/V this equation can also be re-arranged to give the familiar formula for the quantity of charge on the plates as: Q = C x V

Although we have said that the charge is stored on the plates of a capacitor, it is more exact to say that the energy within the charge is stored in an "electrostatic field" between the two plates. When an electric current flows into the capacitor, it charges up, so the electrostatic field becomes much stronger as it stores more energy between the plates.

Likewise, as the current flowing out of the capacitor, discharging it, the potential difference between the two plates decreases and the electrostatic field decreases as the energy moves out of the plates.

The property of a capacitor to store charge on its plates in the form of an electrostatic field is called the Capacitance of the capacitor. Not only that, but capacitance is also the property of a capacitor which resists the change of voltage across it.

Capacitance is the electrical property of a capacitor and is the measure of a capacitors ability to store an electrical charge onto its two plates with the unit of capacitance being the Farad named after the physicist Michael Faraday.

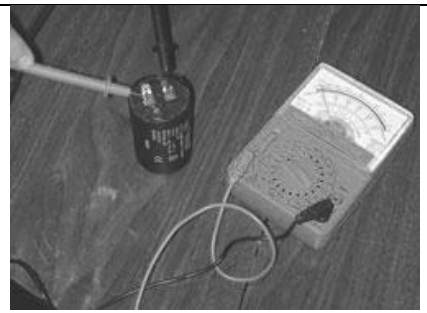
Capacitor has the capacitance of One Farad when a charge of One Coulomb is stored on the plates by a voltage of One volt. Farad is a very large unit of measurement to use on its own so sub-multiples of the Farad is generally used such as micro-farads, nano-farads and pico-farads, for example.

- Micro farad (μF) $1\mu F = 1/1{,}000{,}000 = 0.000001 = 10^{-6}$ F
- Nano farad (nF) $1nF = 1/1{,}000{,}000{,}000 = 0.000000001 = 10^{-9}$ F
- Pico farad (pF) $1pF = 1/1{,}000{,}000{,}000{,}000 = 0.000000000001 = 10^{-12}$ F

How to Test a Capacitor

1. Use screwdriver (with insulated handle) to short the two posts of the capacitor to each other. You might get a spark and pop (if the capacitor is charged).

You need an ANALOG multi-meter. (Volts, Amps, Ohms meter). Use Ohm meter of your multi-meter to measure resistance of the capacitor. Set on relatively large scale, e.g. 1K ohm.



a) If the resistance goes to zero and stays at zero, the capacitor is bad. The capacitor plates are shorted to each other and the capacitor cannot store charge.

b) If the capacitor is good, the reading will go toward zero, and then slowly drift toward high resistance. If you repeat, the needle will move toward zero again, but not as far as the first time, and then drift toward high resistance. Repeat Step 1 to check again if you like.

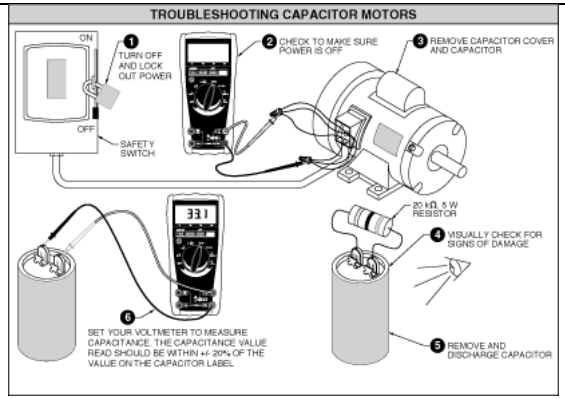
A DIGITAL voltmeter doesn't work as well because the time averaging dilutes the temporal effect needle going toward zero and then drifting back. The needle goes toward zero because the capacitor is being charged current is flowing. Then it stops and drifts backward toward higher resistance because it can no longer accept charge current is no longer flowing.

Describe techniques / procedure for replacement of capacitor

To troubleshoot a capacitor motor, apply the following procedure:

1. Turn the handle of the safety switch or combination starter OFF. Lock out and tag the starting mechanism per company policy.
2. Using a voltmeter, measure the voltage at the motor terminals to make sure the power is OFF.
3. Capacitors are located on the outside frame of the motor. Remove the cover of the capacitor. Caution: A good capacitor will hold a charge, even when power is removed.
4. Visually check the capacitor for leakage, cracks, or bulges. Replace the capacitor if present.
5. Remove the capacitor from the circuit and discharge it. To safely discharge a capacitor, place a 20,000 ohm, 2 W resistors across the terminals for five seconds.
6. After the capacitor is discharged, connect the ohmmeter leads to the capacitor terminals. The ohmmeter will indicate the general condition of the capacitor. A capacitor is good, shorted, or open.

Set your voltmeter to measure capacitance. The capacitance value read should be within ±20% of the value on the capacitor label.



State method of updating the record

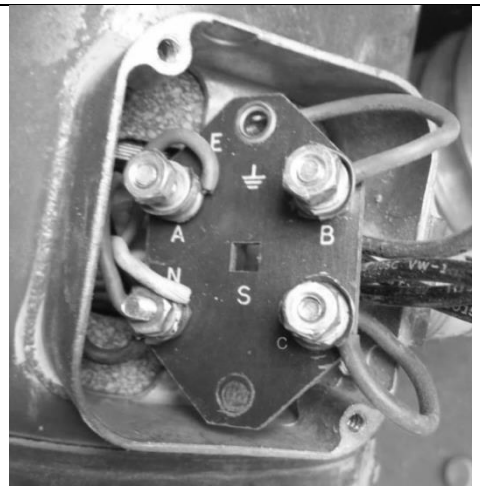
Update the record regarding replacement of capacitor, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of capacitor in history sheet of machine.

LU9. Repair/Replace terminals of Motor

Demonstration regarding selection & use of required Tools, equipment &PPEs

Describe techniques / procedure for checking of terminal plate and terminals of motor

Terminal plate is provided in terminal box. Terminal box is fitted at top or in front portion of its body. Make connections of electric supply in terminal box of motor as per already marked / labeled during dismantling for proper working of motor. Observe the related diagram of motor for proper connection.



Single phase motor terminal plate

Three phase motor terminal plate

Physically check that;

1- The terminal plate is not broken
2- All terminals are free from rust and carbon
3- All linking strips are free from rust and carbon
4- All terminals are tight and no connection is loose
5- All cables have sound connections

6- Air gap between different terminals is in safe condition

- **Describe techniques / procedure for repair of terminal plate / terminals of motor:**
  Cleaning
  Surfacing
  Linking strips
  - Use rust cleaning spray to clean the contacts & linking strips
  - Use file for surfacing if contacts are sparked
  - Use sand paper for polishing contacts and linking strips
- **Describe techniques / procedure for replacement of terminal plate / terminals of motor**
  - Unscrew all the leads from terminal plate one by one after marking the position / numbering on each
  - Unscrew the terminal plate bolts from motor body
  - Remove the faulty terminal plate
  - Take terminal plate of same size & specifications
  - Fit new terminal plate in terminal box
  - Fit the connection leads one by one according to marking
  - Check the looseness of all terminals
- **State method of updating the record**
  Update the record regarding replacement of terminal plate, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the replacement of terminal plate in history sheet of machine.

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-B

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module B: 0713001136 Repair / replace allied parts of machine (Transformer)

Objective: This Modulecovers the knowledge & skills required to Repair / replace allied parts of machine (Transformer through Prepare for work , Collect the required materials/parts , Perform filtration of Transformer Oil , Replace Transformer Oil , Perform De- Hydration of Silica Gel , Repair / Replace Transformer Bushing , Repair/ Replace Tap Changer , Check main Tank body of Transformer for leakage , Check Buchholz Relay ,

Duration: 90 Hours **Theory: 18 Hours** **Practice: 72 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Prepare for work to repair / replace allied parts of machine (Transformer)	**The trainee will be able to:** • Identify the required PPE's • Collect the required PPE's • Identify the required tools and equipment • Collect the required tools and equipment • Ensure functional condition of PPE's/Tools and equipment • Ensure safe working conditions ➢ Clear Passage ➢ Cleanliness ➢ Adequate light ➢ Ventilation	• Recognition of required Tools, Equipment and PPEs to repair / replace allied parts of machine (Transformer). • Importance of functional conditions of required Tools, Equipment and PPEs and their use • Importance of safe working condition regarding ➢ Clear passage ➢ Cleanliness ➢ Adequate light ➢ Ventilation	**Tools** • Spanner Set Screw Driver Set • Allen key Set • Clamp Meter • Safety Belt **Consumables Items** • Hand Gloves • Safety Shoes • Safety Goggles
LU2. Collect the required	**The trainee will be able to:** • Collect list of the estimated material/parts for repair	• Demonstration regarding selection & use of required Tools, equipment &PPEs	**Tools** **Consumable Material** • Lead Pencil

materials/parts	• Check availability of the required parts/material in the store
	• Place purchase order for the deficient parts/materials
	• Collect the required parts/materials from the store
		• State procedure for:
		  • Checking availability of required parts in store according to material list
		  • Collection of required parts from store
		  • Purchase of required parts from market
			• Eraser
			• Paper /
			• Inventory register
			• Required material parts as per list

LU3. Perform filtration & de-hydration of Transformer oil	**The trainee will be able to:**
	• Wear the required PPE's
	• Pick the required tools and equipment
	• Collect oil sample
	• Check the dielectric strength of the oil
	• Drain out oil from transformer tank
	• Perform filtration of transformer oil
	• Perform De-Hydration of transformer oil
	• Update record
		• Demonstration regarding selection & use of required Tools, equipment & PPEs
		• State properties of transformer oil
		• Describe procedure for:
		  • Collection of sample of transformer oil
		  • Testing dielectric strength of transformer oil
		  • Draining out of transformer oil from tank
		• Explain on load / live and off load methods used for filtration / de-hydration of transformer oil
		• State method of updating the record
			Tools
			• Spanner set
			• Adjustable Screw wrench
			• Storage Drum
			• Filtration & De-Hydration plant
			• Transformer oil testing equipment
			Consumable Material
			• Lead Pencil
			• Eraser
			• Paper /
			• Inventory register

LU4. Replace	**The trainee will be able to:**	• Demonstration regarding	**Tools**

Transformer Oil (if needed)	• Wear the required PPE's
	• Pick the required tools and equipment
	• Drain out old transformer oil from tank
	• Arrange new transformer oil
	• Refill new transformer oil in tank
	• Update record
		selection & use of required Tools, equipment & PPEs
		• Describe procedure for:
		  • Draining out of transformer oil from tank
		  • Arranging of new transformer oil
		  • Refilling new transformer oil in tank
		• State method of updating the record
			• Spanner set
			• Adjustable Screw wrench
			• Storage Drum
			• Hand operated oil pump
			Consumable Material
			• Lead Pencil
			• Eraser
			• Paper /
			• Inventory register
			• New Transformer oil

LU5. Perform De- Hydration of Silica Gel	**The trainee will be able to:**
	• Wear the required PPE's
	• Pick the required tools and equipment
	• Open breather of transformer
	• Remove silica gel from breather of transformer
	• Perform de-hydration of silica gel by:
	  ➢ Spreading silica gel under sun light
	  ➢ Heating up silica gel in oven up to 120Cº
	• Update record
		• Demonstration regarding selection & use of required Tools, equipment & PPEs
		• Describe procedure for:
		  • Opening the breather of transformer
		  • Removing silica gel from breather of transformer
		  • Explain different methods used for de-hydration of silica gel
		• State method of updating the record
			Tools
			• Spanner set
			• Adjustable Screw wrench
			• De- Hydration oven
			Consumable Material
			• Lead Pencil
			• Eraser
			• Paper /
			• Inventory register
			• Silica gel
			• Plastic Sheet

LU6. Repair / Replace Transformer Bushings	**The trainee will be able to:**
	• Wear the required PPE's
	• Pick the required tools and equipment
	• Perform physical Checking of transformer bushings
	• Perform cleaning of transformer bushing to remove carbon dust
	• Check the fixing of transformer bushing
	• Replace the damaged transformer bushing
	• Update record
		• Demonstration regarding selection & use of required Tools, equipment & PPEs
		• Describe procedure for:
		  • Physical checking of transformer bushings
		  • Cleaning of transformer bushings
		  • State possible faults of transformer bushings
		  • Checking the fixing of transformer bushings
		  • Replacement of damaged transformer bushings
		• State method of updating the record
			Tools
			• Spanner set
			• Adjustable Screw wrench
			• Combination plier
			• Hammer
			Consumable Material
			• Lead Pencil
			• Eraser
			• Paper /
			• Inventory register
			• Transformer bushings
			• Kerosene oil
			• Petrol
			• Cotton waste
			• Transformer bushing gas kit
			• Samad bond

LU7. Repair/ Replace Tap Changer	**The trainee will be able to:**
	• Wear the required PPE's
	• Pick the required tools and equipment
	• Perform physical Checking of the tap changer
	• Perform cleaning of contact terminals of tap changer to remove carbon dust
	• Check the fixing of tap changer
		• Demonstration regarding selection & use of required Tools, equipment & PPEs
		• Describe procedure for:
		  • Physical checking of transformer tap changer
		  • Cleaning contacts of transformer tap changer
		  • State possible faults
			Tools
			• Spanner set
			• Adjustable Screw wrench
			• Combination plier
			• Hammer
			• Flat File
			Consumable Material
			• Lead Pencil
			• Eraser

	• Check the connections of linking cables • Replace the faulty tap changer • Update record	of transformer tap changer • Checking the fixing of transformer tap changer • Replacement of faulty transformer tap changer • State method of updating the record	• Paper / • Inventory register • Transformer Tap Changer • Sand Paper • Cotton waste • Cotton Tape • Paper Tape • Varnish
LU8. Check main Tank body of Transformer for leakage	**The trainee will be able to:** • Wear the required PPE's • Pick the required tools and equipment • Perform physical Checking of the tank • Locate leakage point in main tank of transformer • Drain out oil from main tank • Refer for welding of the leakage point • Re-fill oil in main tank • Perform physical Checking of the tank • Update record	• Demonstration regarding selection & use of required Tools, equipment & PPEs • Describe procedure for: • Physical checking of transformer tank • Locating of leakage point in transformer tank • Draining out oil from transformer tank • Welding of transformer tank • Refilling of transformer oil in tank • Final checking of leakage point • State method of updating the record	**Tools** • Spanner set • Adjustable Screw wrench • Combination plier • Hammer • Oil Drum • Welding Plant **Consumable Material** • Lead Pencil • Eraser • Paper / • Inventory register • Transformer • Kerosene oil • Cotton waste • Welding Electrode (Rod) • Red Oxide Paint

			• Enamel Spray Paint

LU9.
Repair/Replace Buchholz Relay
	The trainee will be able to:
	• Wear the required PPE's
	• Pick the required tools and equipment
	• Check Buchholz relay
	• Remove Buchholz Relay from transformer
	• Repair/Replace Buchholz relay
	• Update record
		• Demonstration regarding selection & use of required Tools, equipment & PPEs
		• Describe Working principle and possible faults of Buchholz relay
		• Describe procedure for:
		  • Checking of Buchholz relay
		  • Replacement of Buchholz relay
		• State method of updating the record
			Tools
			• Spanner set
			• Adjustable Screw wrench
			• Combination plier
			• Hammer
			Consumable Material
			• Lead Pencil
			• Eraser
			• Paper /
			• Inventory register
			• Transformer Buchholz relay
			• Cotton waste

LU1. Prepare for work to repair / replace allied parts of machine (Transformer) • **Recognition of required Tools, Equipment and PPEs to repair / replace allied parts of machine (Transformer)** • **Importance of functional conditions of required Tools, Equipment and PPEs and their use** • **Importance of safe working condition regarding** ➢ Clear passage ➢ Cleanliness ➢ Adequate light ➢ Ventilation
LU2.Collect the required materials/parts • **Demonstration regarding selection & use of required Tools, equipment &PPEs**

- **State procedure for:**
  - **Checking availability of required parts in store according to material list**
    - Prepare list of required parts which are required to be replaced
    - Verify the availability of these parts from store record
    - Tick / Mark the parts available in store from the list prepared
    - Request for issuance of purchase order of parts which are not available in store
  - **Collection of required parts from store**
    - Prepare requisition form for issuance of parts available in store
    - Collect the parts from store according to requisition
    - Entre these parts in stock register
    - Install parts and update your record
  - **Purchase of required parts from market**
    - Get sign from competent authority on purchase order
    - Get rates from market of required parts
    - Prepare a comparative statement
    - Purchase the required parts from firm quoting lowest rate
    - Enter in store record
    - Collect them from store
    - Enter in your stock register
    - Install parts and update your record

LU3. Perform filtration & de-hydration of Transformer oil

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **State properties of transformer oil**

Transformer oil (also known as insulating oil) is a special type of oil which has excellent electrical insulating properties and is stable at high temperatures. Transformer oil is used in oil-filled electrical power transformers to insulate, stop arcing and corona discharge, and to dissipate the heat of the transformer (i.e. act as a coolant).
Transformer oil is also used to preserve the transformer's core and windings – as these are fully immersed inside the oil. Another important property of the insulating oil is its ability to prevent oxidation of the cellulose-made paper insulation. The transformer oil acts as a barrier between the atmospheric oxygen and the cellulose – avoiding direct contact and hence minimizing oxidation. The level of transformer oil is typically measured using a MOG (Magnetic Oil level Gauge).
There are two main types of transformer oil used in transformers:

1. Paraffin based transformer oil
2. Naphtha based transformer oil

Naphtha oil is more easily oxidized than paraffin oil. But the product of oxidation – i.e. sludge – in the naphtha oil is more soluble than the sludge from the paraffin oil. Thus sludge of naphtha-based oil is not precipitated in the bottom of the transformer. Hence it does not obstruct convection circulation of the oil, means it does not disturb the transformer cooling system.

Although Paraffin oil has a lower oxidation rate than Naphtha oil, the oxidation product (sludge) is insoluble and precipitated at the bottom of the tank. This sludge acts as an obstruction to the transformer cooling system.

Another problem with paraffin-based oil that the dissolved waxes inside of it can lead to a high pour point. Although this is not an issue in warmer climate conditions (such as India).

Despite the disadvantages mentioned above, paraffin-based oil is still commonly used in many countries due to its high availability.

Transformer Oil Properties

The properties (or parameters) of transformer oil are:

1. Electrical properties: Dielectric strength, specific resistance, dielectric dissipation factor.
2. Chemical properties: Water content, acidity, sludge content.
3. Physical properties: Interfacial tension, viscosity, flash point, pour point.

Electrical Properties of Transformer Oil

Dielectric Strength of Transformer Oil

The dielectric strength of transformer oil is also known as the breakdown voltage (BDV) of transformer oil. Breakdown voltage is measured by observing at what voltage, sparking strands between two electrodes immersed in the oil, separated by a specific gap. A low value of BDV indicates presence of moisture content and conducting substances in the oil.

Dry and clean oil gives BDV results, better than the oil with moisture content and other conducting impurities. Minimum breakdown voltage of transformer oil or dielectric strength of transformer oil at which this oil can safely be used in transformer, is considered as 30 KV.

Specific Resistance of Transformer Oil

This is another important property of transformer oil. The specific resistance of oil is a measure of DC resistance between two opposite sides of one cm^3 block of oil. Its unit is ohm-cm at a specific temperature. With increase in temperature the resistivity of oil decreases rapidly.

Just after charging a transformer after long shut down, the temperature of the oil will be at ambient temperature and during full load, the temperature will be very high and may go up to 90^oC at an overload condition. So resistivity of

the insulating oil must be high at room temperature and also it should have good value at high temperature as well. That is why specific resistance or resistivity of transformer oil should get measured at 27^oC as well as 90^oC.
Minimum standard specific resistance of transformer oil at 90^oC is 35×10^{12} ohm–cm and at 27^oC it is 1500×10^{12} ohm–cm.

Dielectric Dissipation Factor of Tan Delta of Transformer Oil

Dielectric dissipation factor is also known as loss factor or tan delta of transformer oil. When a insulating materials is placed between live part and grounded part of an electrical equipment, leakage current will flow. As an insulating material is dielectric in nature the current through the insulation ideally leads the voltage by 90^o. Here voltage means the instantaneous voltage between live part and ground of the equipment. But in reality, no insulating materials are perfect dielectric in nature.

Chemical Properties of Transformer Oil

Water Content in Transformer Oil

Moisture or water content in transformer oil is highly undesirable as it affects the dielectric properties of the oil adversely. The water content in oil also affects the paper insulation of the core and winding of a transformer. Paper is highly hygroscopic. Paper absorbs the maximum amount of water from oil which affects paper insulation property as well as reduced its life. But in a loaded transformer, oil becomes hotter, hence the solubility of water in oil increases.
As a result, the paper releases water and increase the water content in transformer oil. Thus the temperature of the oil at the time of taking a sample for the test is critical. During oxidation, acids get formed in the oil the acids give rise to the solubility of water in the oil. Acid coupled with water further decompose the oil forming more acid and water. This rate of degradation of oil increases. We measure the water content in oil as ppm (parts per million unit).
The water content in oil is allowed up to 50 ppm as recommended by IS–335(1993). The accurate measurement of water content at such low levels requires very sophisticated instrument like Coulometric Karl Fisher Titrator.

Acidity of Transformer Oil

Acidic transformer oil is a harmful property. If oil becomes acidic, the water content in the oil becomes more soluble in the oil. The acidity of oil deteriorates the insulation property of paper insulation of winding. Acidity accelerates the oxidation process in the oil. Acid also includes rusting of iron in the presence of moisture.
The acidity test of transformer oil can be used to measure the acidic constituents of contaminants. We express the acidity of oil in mg of KOH required to neutralize the acid present in a gram of oil. This is also known as neutralization number.

Physical Properties of Transformer Oil

Inter Facial Tension of Transformer Oil

Interfacial tension between the water and oil interface is the way to measure the attractive molecular force between water and oil. in Dyne/cm or milli-Newton/meter. Interfacial tension is exactly useful for determining the presence of polar contaminants and oil decay products. Good new oil generally exhibits high interfacial tension. Oil oxidation

contaminants lower the IFT.

Flash Point of Transformer Oil

Flash point of transformer oil is the temperature at which oil gives enough vapors to produce a flammable mixture with air. This mixture gives momentary flash on the application of flame under standard condition. Flashpoint is important because it specifies the chances of fire hazard in the transformer. So it is desirable to have a very high flash point of transformer oil. In general it is more than 140^{o}($>10^{o}$).

Pour Point of Transformer Oil

It is the minimum temperature at which oil starts to flow under standard test condition. Pour point of transformer oil is a valuable property mainly at the places where the climate is icy. If the oil temperature falls below the pour point, transformer oil stops convection flowing and obstruct cooling in a transformer. Paraffin-based oil has a higher value of pour point, compared to Naphtha based oil, but in India like country, it does not affect the use of Paraffin oil due to its warm climate condition. Pour Point of transformer oil mainly depends upon wax content in the oil. As Paraffin-based oil has more wax content, it has higher pour point.

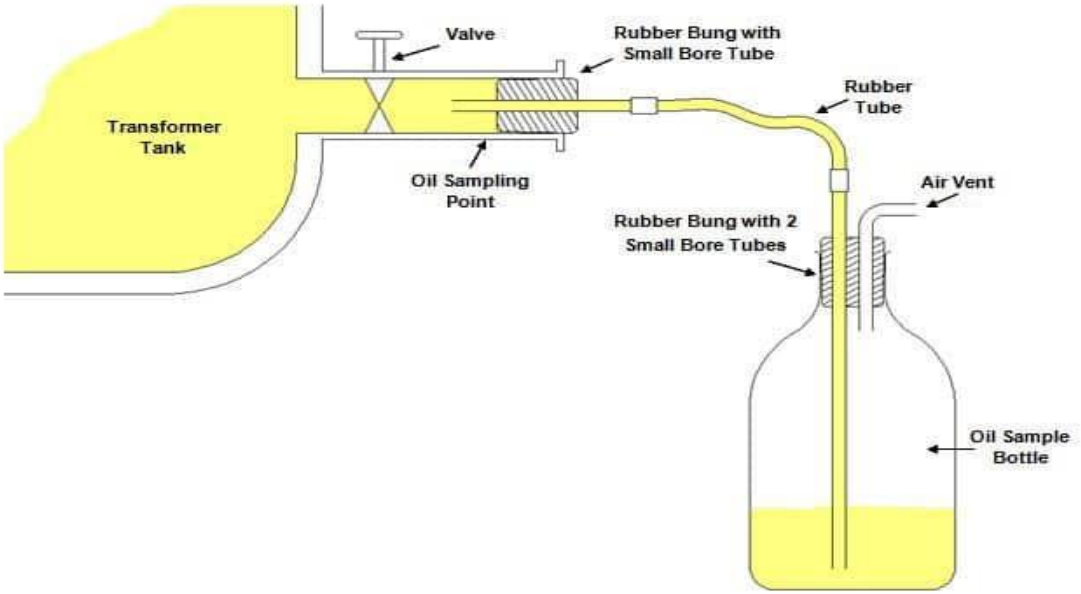
Viscosity of Transformer Oil

In few words, the viscosity of transformer oil can be said that viscosity is the resistance of flow, in normal condition. Resistance to flow of transformer oil means obstruction of convection circulation of oil inside the transformer. Good oil should have a low viscosity so that it offers less resistance to the conventional flow of oil thereby not affecting the cooling of a transformer. Low viscosity of transformer oil is essential, but it is equally important that the viscosity of oil should increase as less as possible with a decrease in temperature. Every liquid becomes more viscous if the temperature decreases.

- **Describe procedure for:**

Collection of sample of transformer oil

Takeoil sampling kit**.** It's important to keep any sampling kit clean after use so it is kept in a good condition and can then be re-used for future sampling requirements.



There is a step by step process that should be followed and if done correctly will ensure a good quality and representative sample is taken:

- Check the weather…if it's raining try to avoid taking a sample, aim for a nice dry, warm day. Not always

possible to plan the weather so erect a canopy / tent over the unit and sampling point and ensure to keep all kit clean and dry. A small amount of rain can affect your results dramatically.

- Clean the sample tap before any sampling is started; use a wire brush and/or lint free cloth to remove and debris form the external surface.
- Connect the correct size oil resistance rubber bung to the sample tap by pushing or tapping it on and don't forget to attach the stainless-steel tube to the pre-drilled hole.
- Always drain at least 500ml of oil out of the unit and to a waste container before taking your sample, this ensures any debris is flushed out before you take your sample… VERY important.
- The temperature of the flowing oil should be recorded and noted on the sample label, this is required for any accurate moisture determination.
- Rinse out the bottle with the oil to ensure it is clean and warmed so any debris or condensation is removed.
- Attach the bottle bung with inlet tube and air vent tube to the sample bottle. The stainless-steel tube should extend to the bottom of the bottle and ensure a slow flow rate to cause minimum air displacement and oil disturbance.

The bottles should be allowed to overflow and tubing should be withdrawn slowly and the bottle should be tipped to allow some oil to flow out leaving approximately 2cm head space. The reason for this is to allow space for any thermal expansion or volatile gas's within the sample but not leaving too much which will allow gas to escape from the oil into the headspace.

The cap should be securely screwed onto the sample vessel.

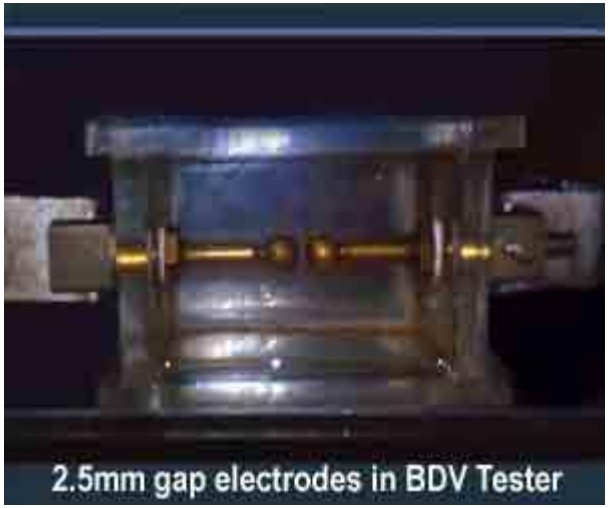
The sample should be cleaned, clearly labeled and securely and safely packed in a carry case or box to ensure safe transport to the lab.

Testing dielectric strength of transformer oil

For mineral oil, a generally accepted minimum dielectric strength is 30 kV for transformers with a high-voltage rating of 230 kV and above and 27 kV for transformers with a high-voltage rating below 230 kV. New oil should have a minimum dielectric strength of 35 kV by ASTM methods of testing.

https://www.electrical4u.com/images/BDV-Tester.jpg

The dielectric strength of transformer oil is also known as the breakdown voltage (BDV) of transformer oil. Breakdown voltage is measured by observing at what voltage, sparking strands between two electrodes immersed in the oil, separated by a specific gap. A low value of BDV indicates presence of moisture content and conducting substances in the oil.



https://www.electrical4u.com/images/electrodes-in-bdv-tester.jpg

For measuring BDV of transformer oil, portable BDV measuring kit is generally available at site. In this kit, oil is kept in a pot in which one pair of electrodes are fixed with a gap of 2.5 mm (in some kit it 4mm) between them. Now slowly rising voltage is applied between the electrodes. The rate of rising voltage is controlled at 2 KV/s and observes the voltage at which sparking starts between the electrodes. That means at which voltage dielectric strength of transformer oil between the electrodes has been broken down.
This measurement is taken 3 to 6 times in the same sample of oil, and we take the average value of these readings. BDV is an important and popular test of transformer oil, as it is the primary indicator of the health of oil and it can be easily carried out at the site.
Dry and clean oil gives BDV results, better than the oil with moisture content and other conducting impurities. Minimum breakdown voltage of transformer oil or dielectric strength of transformer oil at which this oil can safely be used in transformer, is considered as 30 KV.

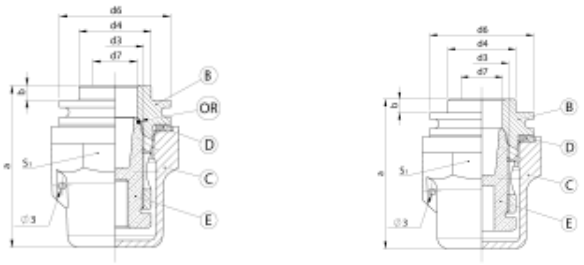
Flash Point of Transformer Oil

Flash point of transformer oil is the temperature at which oil gives enough vapors to produce a flammable mixture with air. This mixture gives momentary flash on the application of flame under standard condition. Flashpoint is important because it specifies the chances of fire hazard in the transformer. So it is desirable to have a very high flash point of transformer oil. In general it is more than 140^{o} ($>10^{o}$).

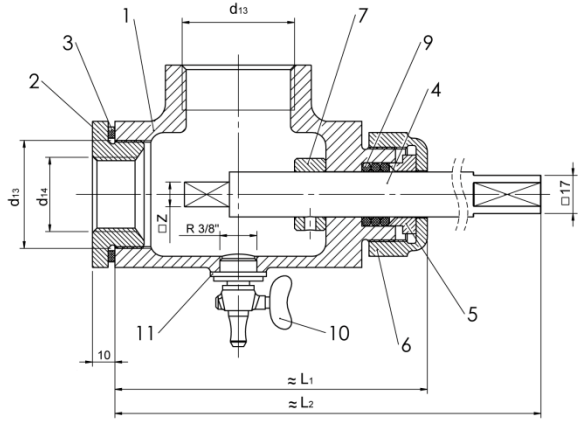
Draining out of transformer oil from tank

The oil drain device built-in O-ring prevents accumulation of oil in the stop plug. The function of the connection pipe F is completely preserved. The oil drain device has advantage of the additionally safety against leakage, as well as no oil in stop plug, which prevents contamination when the cap will be removed.

Standard Type ***O-ring Type***



The connection pipe is a maintenance-tool to connect the oil drain device to an extern oil-system. The connection pipe is manufactured in two sizes.



Explain on load / live and off load methods used for filtration / de-hydration of transformer oil

Insulating oil filtration process

Rising oil temperature

First step is to raise oil temperature up to 65°C to give latent heat which separates moisture and gases. Heating the

oil will make it easier to filter because of the decrease in oil viscosity.

Removal of dirt and impurities

Second step is to remove sludge and dirt from the insulating oil. There are 2 ways to eliminate dirt in the transformer oil.

By filter candles

Insulating oil filtration by filter candles can be classified by using classical edge filter or depth type filter. However, new advancements were made in which transformer oil filtration machines use filter cartridges instead of edge type paper filters.

By centrifuging action

Another method for separating dirt from oil is through centrifuging. With this process, you can save recurring cost of changing filters.

Dehydration and degasification of insulating oil

This is the stage of dehumidification of insulating oil and removal of gasses. This process is completed in the degassing chamber.

Transformer oil deterioration should be minimized

Research shows that 80% of oil related failures and breakdowns are caused by contaminated oil. Preventive oil maintenance is therefore an important factor to ensure optimum equipment reliability. A successful insulating oil filtration procedure can be achieved by using reliable transformer oil filtration equipment. This will extend the effectiveness and reliability of your transformer. Transformer oil filtration is a great help to any businesses. Thus, good transformer oil filtration equipment is needed. There are many companies that offer different kinds of equipment. However, choose a vendor that manufactures high quality insulation oil purification machine that can ensure high Return on Investment (ROI).

State method of updating the record

Update the record regarding testing / replacement of transformer oil; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the testing /

replacement of transformer oil in history sheet of transformer.

LU4. Replace Transformer Oil (if needed)

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe procedure for:**
  - **Draining out of transformer oil from tank**
  - **Arranging of new transformer oil**
  - **Refilling new transformer oil in tank**

Described below are the phases that make up the filling process of electric power equipment with a maximum voltage greater than 72.5 KV.

. **Preliminary treating the filling oil**

. The filling oil is transferred into tanks and subjected to physical treatment (filtration, degassing and dehydration in a vacuum). The purpose is to obtain oil with parameters that conform to IEC 60296.

. **Preparation of the transformer with a vacuum**

. The accessories and components which cannot resist the vacuum are isolated by closing the shut-off valves or applying blind flanges. Then a sensor is applied to measure the vacuum and a vertical pipe to monitor the oil level inside the tank during filling.

. **Application of vacuum**

. The vacuum is applied until a residual pressure of less than 2 mbar (200 Pa) is obtained and maintained for the duration of between 12 and 36 hours according to the maximum voltage of the machine to be filled. During this draining step the tightness of the seals is checked

. **Partial filling with a vacuum**

. The oil is inserted into the caisson through the bottom gate until completely covering the reels, while maintaining the suction of the vacuum in the upper part. Upon reaching a level of about 20 cm with respect to the lid, the vacuum pipe is shut off and the filling is continued, filling up to the Buchholz relay. In cases where the connection is to the tank, it is completely filled (see next step).

.

Final filling and checking of levels and vents

Filling accessories

The separated accessories (variators, radiators, AT passers tanks) that are resistant to the vacuum are filled simultaneously with the main caisson; the ones that are not resistant to the vacuum are filled after the transformer.

Final oil treatment

The oil is subjected to a final filtration treatment, degassing and dehydration with a vacuum by continuously circulating it in a closed circuit. The oil treatment should ensure that all regulatory requirements are met, as well as technical and contractual ones and therefore counter any cross contamination.

State method of updating the record

Update the record regarding filling of transformer oil, this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record the filling of transformer oil in history sheet of transformer.

LU5. Perform De- Hydration of Silica Gel

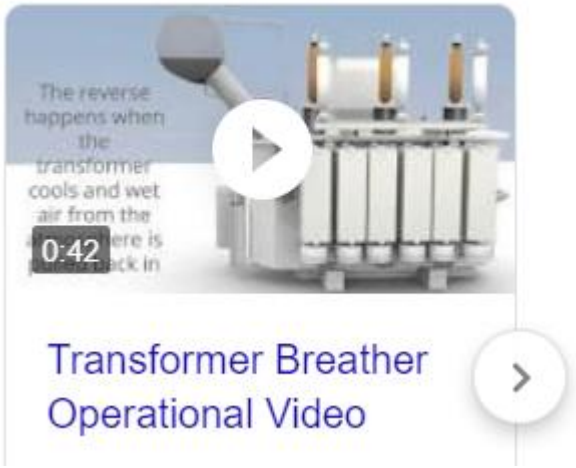
- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe procedure for:**
    - **Opening the breather of transformer**

The function of breather in transformer is to filter out the moisture from air. Breather consists of silica gel which absorbs the moisture from air.

When there is overloading on transformer, the winding of transformer gets heated so the oil in main tank of transformer also get heated. The hot oil started expanding. There is conservator tank at the top of transformer which allows adequate space for expansion of oil. Therefore during overloading condition the oil moves to the conservator tank.

In normal operating condition, the oil comes back to main tank from conservator tank. Now, there is vacant space in the conservator tank which is filled with the air. Conservator tank is never completely filled as it has to allow space for expanding oil from main tank.

The air which is there in conservator tank is coming from atmosphere through the breather and breather contains silica gel in it. This silica gel absorbs the moisture from air. The main reason to remove moisture from air is because the moisture degrades the dielectric strength of the transformer oil.



https://www.youtube.com/watch?v=r4mcJXEZ3rs

Removing silica gel from breather of transformer

Whenever electrical power transformer is loaded, the temperature of the transformer insulating oil increases, consequently the volume of the oil is increased. As the volume of the oil is increased, the air above the oil level in conservator will come out. Again at low oil temperature; the volume of the oil is decreased, which causes the volume of the oil to be decreased which again causes air to enter into conservator tank.

The natural air always consists of more or less moisture in it and this moisture can be mixed up with oil if it is allowed to enter into the transformer. The air moisture should be resisted during entering of the air into the transformer, because moisture is very harmful for transformer insulation. A silica gel breather is the most commonly used way of filtering air from moisture.

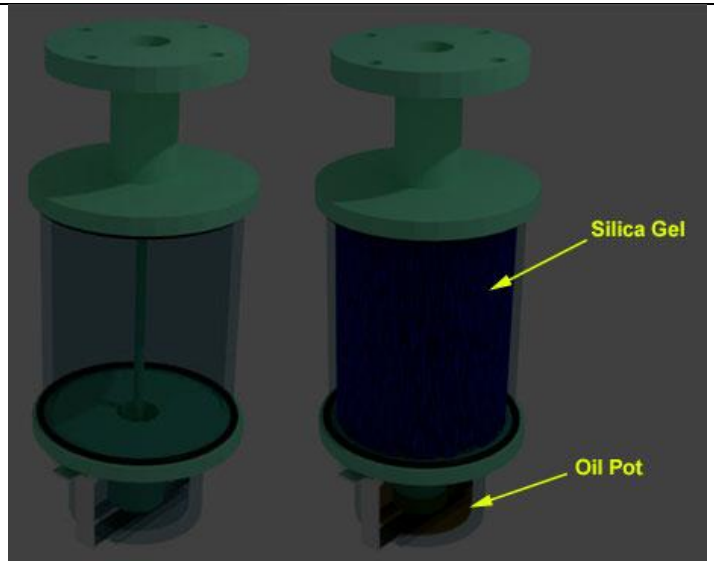
Silica gel breather for transformer is connected with conservator tank by means of breathing pipe.

SILICA GEL BREATHER

The silica gel breather of transformer is very simple in the aspect of design. It is nothing but a pot of silica gel through which, air passes during breathing of transformer. The silica gel is a very good absorber of moisture. Freshly regenerated gel is very efficient; it may dry down air to a dew point of below -40^{o}C. A well maintained silica gel breather will generally operate with a dew point of -35^{o}C as long as a large enough quantity of gel has been used. The picture shows a silica gel breather of transformer.

Silica gel crystal has tremendous capacity of absorbing moisture. When air passes through these crystals in the breather; the moisture of the air is absorbed by them. Therefore, the air reaches to the conservator is quite dry, the dust particles in the air get trapped by the oil in the oil seal cup. The oil in the oil sealing cup acts as barrier between silica gel crystal and air when there is no flow of air through silica gel breather. The color of silica gel crystal is dark blue but, when it absorbs moisture; it becomes pink.

When there is sufficient difference between the air inside the conservator and the outside air, the oil level in two components of the oil seal changes until the lower oil level just reaches the rim of the inverted cup, the air then moves from high pressure compartment to the low pressure compartment of the oil seal. Both of these happen when the oil acts as core filter and removes the dust from the outside air.



Explain different methods used for de-hydration of silica gel

There are two methods used for re-drying silica gel. One method uses the oven, and the other uses the microwave. When you use either method please observe all the safety precautions described below:

1. Oven drying method:

This method gives the best results even though it takes longer. Set the oven for 275 deg. F. Place the silica gel in appropriates container and dry the gel until it turns medium blue. The oven drying method takes approximately 1 ½ hours per quart of gel. One quart of gel weighs approximately 30 ounces.

2. Microwave drying method:

Place the silica gel in an appropriate container and set the microwave power to the medium to medium high setting. Dry for approximately 3 to 5 minutes and inspect the gel for color change. If the gel has not dried, stir it with a spoon and heat it for another 3 to 5 minutes. Stir the gel each time it is inspected. Approximate drying time is 8 to 12minutes per pound of gel. The actual heating times will vary according to the type of microwave. You may set the power setting on high but please be careful not to overheat the gel.

Safety Precautions

• You are responsible for the safe and proper use of this product. Do not use this product in away that it was not intended, or without following the precautions below.

• Use only a very thick Pyrex baking dish to dry the gel. A 9” X 9” baking dish works well. The glass should be approximately ¼” thick. Do not use a Pyrex pie plate, or other than glass, which may shatter if overheated. As a

precaution, do not handle or move a hot Pyrex dish. Do not use plastic or microwave dishes for drying silica gel because the hot beads may cause the dish to melt.

•Silica gel gets very hot during the drying process. Do not attempt to handle silica gel, or the container, until it has cooled to a safe temperature. We do not recommend moving hot silica gel. If you must move it while it is hot, use a hot pad. Be aware that glass may shatter if it is of the wrong type, is too thin, or is unevenly heated.

• Do not overheat the gel. If you overheat the gel you may ruin it, and it will take longer and longer to re-dry the gel. It is better to under-heat it, than overheat it. It is better to re-dry small batches than large batches. One indicator of overheated silica gel is the presence of black or blue-black silica beads.

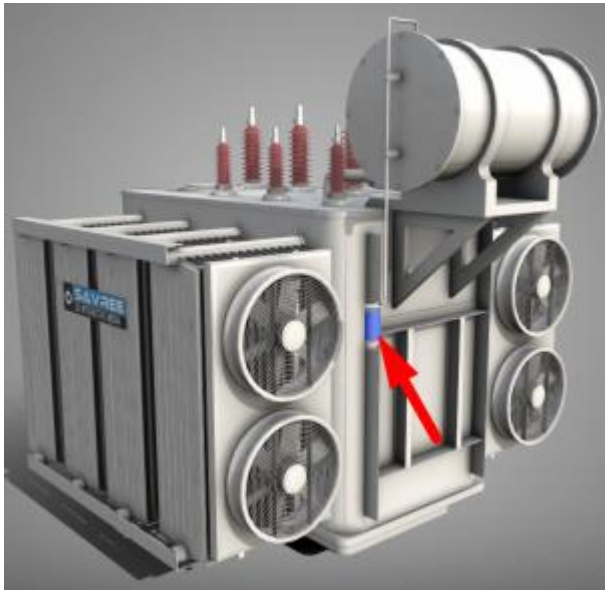
• You may notice a light odor when drying the silica gel. The manufacturer states that this is due to organic volatile compounds which are absorbed into the silica gel during the drying process. These volatiles may be released as the silica gel is re-dried. Extreme over-heating may cause the release of a stronger odor, possibly related to the breakdown of the gel. If there is odor, we suggest using the oven method for drying. Use adequate ventilation as a sensible precaution.

• Do not transfer silica gel to another storage container until the gel has thoroughly cooled. If the gel has not cooled you'll notice the presence of condensation on the walls of the storage container. Canning jars make good containers for storing silica gel.

• According to the manufacturer, silica gel is chemically inert, non-corrosive, non-toxic, and odorless. Silica gel is often found in household products. For example it is often packaged with vitamins to keep the contents dry. It is also commonly packaged with shoes and electronic instruments. Even though silica gel is non-toxic, even if accidentally ingested, we suggest that you keep it away from small children.

Dehydrating breathers, sometimes referred to as silica gel breathers, prevent moisture from ambient air coming into contact with an electrical transformer's insulating liquid. The breather contains hydrophilic (attracted to water) crystal or bead shaped silica gel. Within the transformer industry, silica gel is the preferred drying agent although other options are available.

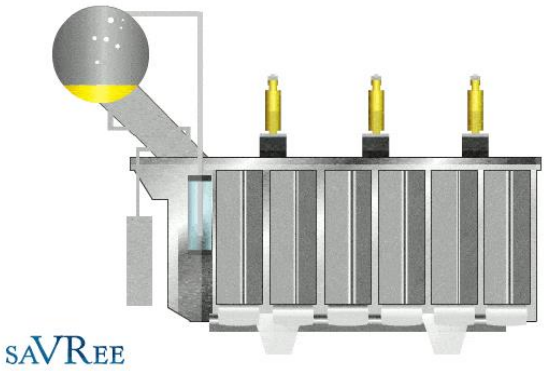
Breathers are fitted to all conservator type liquid immersed transformers. A hermetic liquid insulated transformer does not require a dehydrating breather because the transformer tank is completely sealed and the insulating liquid has no contact with ambient air.



Location of Dehydrating Breather on Conservator Transformer

Function of Transformer Dehydrating Breather

Dehydrating breathers are simple yet critical pieces of equipment required for maintaining a healthy electrical transformer. As the transformer load varies, so too does the temperature. As the temperature increases, the insulating liquid volume increases and air is forced out of the conservator tank. As the temperature decreases, the oil volume decreases and air is drawn back into the conservator tank via the silica gel breather (see animation below).



Transformer 'Breathing' Due to Changing Temperature

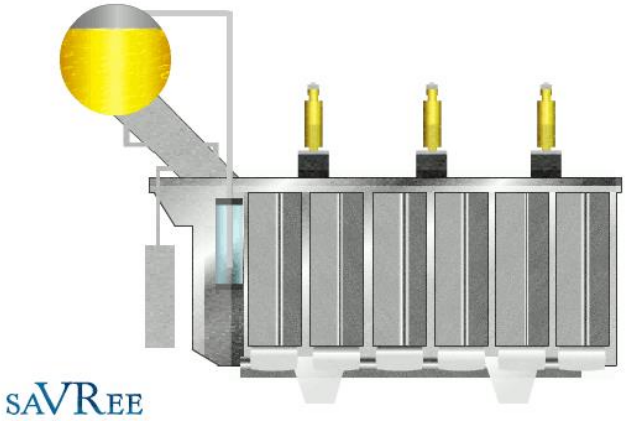
If the transformer tank was not vented (open to atmosphere), the change in temperature would create a positive pressure within the transformer tank as the temperature increases, and a negative pressure when the temperature decreases. However, venting to atmosphere creates additional complications.

Ambient air contains many undesirable foreign bodies and these must be prevented from coming into contact with the transformer insulating liquid. Moisture contained within the air is particularly hazardous to transformer insulating liquid as it has a detrimental effect upon the insulating liquid's dielectric strength and can cause a significant reduction in the transformer's useful working life.

How Dehydrating Breathers Work

As the transformer cools, the insulating liquid volume decreases and air is drawn to the conservator tank via the breather. Moisture within the air is absorbed by the silica gel as it passes through the breather. Silica gel can absorb

approximately 20**%** of its weight in moisture before it becomes saturated e.g. 5 kg of silica gel can absorb approximately 1 kg of water.



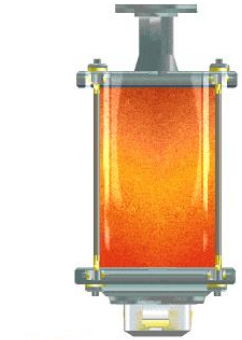
https://savree.com/wp-content/uploads/2018/04/Transformer-breathing-in-and-out.gif

Transformer Inhaling Air

In addition to its dehydrating function, the breather has a second function. An oil trap located beneath the breather isolates the silica gel from ambient air when there is no/little pressure difference between the conservator tank and the ambient air. The oil trap forms a barrier through which air cannot freely flow, thus the silica gel is not constantly absorbing moisture and the intervals between regenerating (drying-out) the silica gel can be extended. The oil trap also attracts dust particles from the air when air does enter the breather; this reduces the likelihood of insulting liquid contamination.

When to Change the Silica Gel

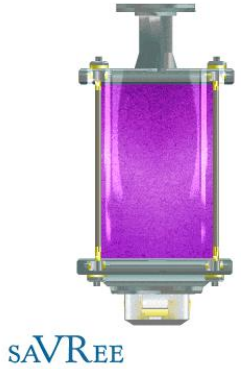
The silica gel will absorb moisture from the air until it becomes saturated, at which point it will no longer be effective. Fortunately, it is very easy to know when silica gel must be replaced or regenerated (a process known as regeneration). As the silica gel becomes saturated, it will change colour, starting at the bottom and spreading upwards. Typical colours employed today are orange (dry) changing to clear (saturated).



https://savree.com/wp-content/uploads/2018/04/Transformer-silica-gel-breather-changing-from-orange-to-white.gif

Silica Gel Breather Becoming Saturated

Or, purple (dry) changing to pink (saturated).



https://savree.com/wp-content/uploads/2018/04/Transformer-silica-gel-breather-changing-from-purple-to-pink.gif

Silica Gel Breather Becoming Saturated

It is generally advised to keep a 5-10 cm (2-4 inches) 'buffer' of dry silica gel at all times, but regenerating or replacing the silica gel when it is 1/3 is saturated is best practice. Having less than 1/3 dry silica gel within the breather increases the likelihood that some moisture will reach the transformer insulating liquid and contamination will occur.

Silica Gel Regeneration

Many people replace the silica gel when it becomes saturated although this is usually not necessary. The absorbed moisture will liberate itself from the silica gel if exposed to elevated temperatures, thus it is possible to restore the silica gel to its former non-saturated state. Typical means for regenerating silica gel include placing the silica gel beads on a hot surface and allowing for them to dry.

How to Check the Breather is working

There are two easy ways to ensure the breather is working correctly.

1. Look for bubbles passing through the oil trap.
2. Check the silica gel colour is changing over time.

If the silica gel does not change colour over time, there is a strong possibility that the transformer has a leaking gasket or seal, and air is entering and exiting through the leak. Leaking gaskets and seals should be found and replaced as soon as possible.

Breather Rating

Breathers are purchased based upon their drying capacity per volume of insulating liquid. For example, a transformer utilizing 5,000 liters of insulating liquid will require a smaller breather than a transformer utilizing 30,000 liters. The breather size is usually determined by the transformer original equipment manufacturer (OEM).

State method of updating the record

Update the record regarding dehydration of silica gel; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record this in history sheet of transformer.

LU6. Repair / Replace Transformer Bushings

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe procedure for:**
    - **Physical checking of transformer bushings**

A transformer bushing is an insulating structure that facilitates the passage of an energized, current-carrying conductor through the grounded tank of the transformer. The conductor may be built in to the bushing, i.e., a bottom-connected bushing, or the bushing may be built with the provision for a separate conductor to be drawn

through its centre, a.k.a., a draw-lead or draw-rod bushing.

The two principal types of bushing construction are solid or bulk type and capacitance-graded (sometimes called condenser type). The bushings used for the low voltage winding(s) of a transformer are often solid type with a porcelain or epoxy insulator. Capacitance-graded bushings, designed for higher voltage ratings, are used for a transformer's high voltage winding.

Unlike a solid type construction, in a capacitance-graded transformer bushing, conducting layers are inserted at predetermined radial intervals within the insulation that separates the centre conductor from the insulator (housing) of the bushing. These multiple conductive inserts create capacitive elements linking the centre conductor of the bushing to ground. Their purpose is to control the voltage field around the center conductor so that the voltage distributes more uniformly across the surrounding insulation system in the bushing.

In solid type bushings, electrical grade mineral oil is often used between the conductor and the insulator, which may be contained within the bushing or shared with the transformer. Typical insulation used in a capacitance-graded bushing is oil-impregnated paper (OIP), resin-impregnated paper (RIP), and resin bonded paper (RBP). Capacitance-graded bushings also use mineral oil, usually contained within the bushing.

Transformer bushing failures are often credited as one of the top causes of transformer failures so the condition of the bushings is of high interest to transformer asset owners. Typical bushing failure modes include moisture ingress, electrical flashover, lightning strike, short-circuited capacitance-graded layer(s), bushing misapplication, corrosive sulphur, broken connection between ground sleeve and flange, and a broken tap connection. The following electrical field tests provide information about the integrity of the bushings.

Bushing diagnosis

- C1 and C2 tests should be performed on a capacitance-graded bushing. A C1 power factor/dissipation factor test checks the health of the bushing's main core insulation, while the C2 measurement is used to assess the bushing tap compartment's insulation plus the outermost main core insulating wraps and surrounding filler material. Often, C2 serves as early detection for moisture ingress or other contaminants that collect around the flange area because of a deteriorated or faulty top terminal gasket, for example.
- An increase in C1 capacitance for example may indicate short-circuited capacitance-graded layers in the bushing, a diagnosis which warrants the bushing's immediate replacement.

- A hot collar test is used routinely for solid type bushings without taps and is effective in revealing deterioration, contamination, low compound or liquid levels, and voids in the compound (if applicable). It may also be effective as a supplementary test to C1 and C2 tests on capacitance-graded bushings with taps.

Cleaning of transformer bushings

There are six different inspections to be performed on the bushings of the power transformer:

1. Routine inspection
2. Regular inspection (Once every two years)
3. Inspection due to excessive partial heating's
4. Local damages inspection (fissures) on the bushings
5. Inspection for oil leaks
6. Storage

1. Routine inspection

Excessive local heating

Pay attention to the clamping section of the terminals**.** It is convenient to paint this section with heat indicating paint.

Pollution

When there is much dust and salt, a cleanup must be performed and to do so, the transformer must be place out of service and use water, ammonia or carbon tetrachloride. If they are very dirty, use concentrated hydrochloric acid diluted 40 or more times in water.

The solution should not be in contact with any metallic part; after the cleaning the porcelain parts, these must be neutralized with water that contains sodium bicarbonate in a proportion of 30 grams by liter.

As long as it uses a chemical solution, make sure of washing it after with fresh water, so that no strange elements are left.

In systems in which will be difficult to stop the operation of the transformer for cleaning, or in zones where there are many damages by the dust or the salt, it is being using recently a washing method designated "of hot line**"**. It isa method to wash the equipment without stopping its operation, and there are 2 or 3 forms of doing it.

In any case, it must be verified the degree of dust and salt, the quality of the water to wash and the method of waterproofing when the cleaning is done.

Mechanical damages

Check if there are any damages or oil leaks in the bushings**.**

2. Regular inspection (Once every two years)

Evaluation of the deterioration of the insulation

The measurement of the insulation resistance in the bushings is not simple, since the bushing and the winding of the transformer should be independent; nevertheless, the measurement must be made the best way possible.

The bushings should be separated from the transformer in most cases. The evaluation of the result of the measurement should not depend solely on the absolute values obtained, but on the values obtained each year and from the variation among them. If there are large discrepancies in the values, special attention is necessary.

When the insulation resistance is superior to 1000 MΩ at normal temperatures, it can be considered as good condition**,** but the value of the tan also must be taken into consideration for the evaluation.

3. Inspection due to excessive partial heating's

The excessive heating of the terminals in most cases is due to loosening. If this condition is observed, eliminate the dust or dirt from the parts from contact and tighten firmly.

4. **Local damages inspection (fissures) on the bushings**

The cleaning of the bushings must be done according to what was mentioned. If the damages are very serious it must be replaced with new ones.

5. **Inspection for oil leaks**

Check the various pieces of the bushings to see if there is any oil leaks. If oil is leaking through the gasket, tighten it or replace it. If there are bushings of immersed in oil type and the oil leak is through other part of the bushing, report it to the manufacturer.

Keep the bushings in a vertical position and in a dry place. It is recommended to keep them in their original packaging.

6. **Storage**

Keep the bushings in a vertical position and in a dry place. It is recommended to keep them in their original packaging.

State possible faults of transformer bushings

Bushes are insulating devices that insulate a high voltage electrical conductor to pass through an earth conductor. In transformers it provides a current path through the tank wall. Inside the transformer paper insulators are used which are surrounded by oil that provides further insulation. Bushing failure usually occurs over time. Some of the main

reasons for bushing failure are discussed below.

A. Loosening of conductors is caused by transformer vibrations which results in overheating. This heat damage the insulating paper and the oil used.

B. Sudden high fault voltages causes' partial discharge (breakdown of solid/liquid electrical insulators) which damage the bushes and causes its degeneration and complete breakdown within hours.

C. Seal breaking of bushes happen due to ingress of water, aging or excessive dielectric losses. Due to this fault core failure of the transformer occurs.

D. Not replacing of old oil over long time or its deficiency due to leakage causes internal over-flashing.

- **Checking the fixing of transformer bushings**

https://www.youtube.com/watch?v=XmNAb8i96W4

- **Replacement of damaged transformer bushings**

https://www.google.com/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjOoo_yr4DlAh

WOMBQKHfYKBTAQjB16BAgBEAM&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DZitsZR5ozYQ&psig=AOvVaw1L0WbQmT0ALdg7N8MA54dr&ust=1570200976992969

State method of updating the record

Update the record regarding checking, cleaning & replacement of transformer bushings; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record this in history sheet of transformer.

LU7. Repair/ Replace Tap Changer

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe procedure for:**
  - **Physical checking of transformer tap changer**
  - **Cleaning contacts of transformer tap changer**
  - **State possible faults of transformer tap changer**

The tap changer function in the transformer is to regulate the voltage level. Taps are provided at the HV windings of the transformer because of the following reasons.

1. The number of turns in the High voltage winging is large and hence a fine voltage variation can be obtained.
2. The current on the low voltage winding of large transformers are high. Therefore interruption of high currents is a difficult task.
3. LV winding is placed nearer to the core and HV winding is placed outside. Therefore providing taps on the HV winding is comparatively easier than that of the LV winding.

It is the most complex part of the transformer and also an important one. Even the smallest fault results in the wrong power output. Some fault and causes are;

A. In Run-Through fault the tap changer takes time and after a delay changes the turn ratio. The main reason for it is the relay responsible for the tap change has residue flux because of polluted oil, therefore taking time to change. The other reason for run-through fault is the spring becoming fragile over time.

B. Lack of maintenance causes the shaft connection between the tap and the motor driver of the tap changer to be not synchronous. Because of this the tap changer is not in the position where it needs to be.

C.Old capacitors or burned-out capacitor in the motor causes the tap changer to fail to control its direction movement.

D. Regular use of the tap changer causes the spring in it to slowly become fragile over time and then finally break. Because of this the tap changer is not able to change the turn ratio of the winding.

E. Breakdown of the motor in the tap changer because of over voltage or miss-use also causes the tap changer to fail to change the turn ratio of the winding.

Checking the fixing of transformer tap changer

The checking of tap changer helps to diagnose the faults and to rectify them accordingly. Checking is performed by physically checking the condition of tap changer and also some tests are performed, the detail has been shown below.

Measurement method	Application/ purpose	Problems
Static winding resistance	Check the windings as well as the internal connections	Contacts alignment, contact wear
Vibrio-acoustic	Detect acoustical signals caused by mechanical movement Linkage/gears	Timing/Sequence, contacts alignment, arcing, overheating/coking, contact wear
Transition Position and torque	Detect mechanical problems and aging of the drive mechanism	Linkage/gears, control/relays, motor, brake, lubrication, contacts alignment
Dissolved gas analysis	Detect higher concentration of gasses in the tap changer compartment	Arcing overheating/coking
Dynamic resistance	Measure the fast switching process of the diverter switch	Timing/sequence, contact wear, transition

Methods for tap changer testing

1- Winding resistance measurements (static)

Winding resistance measurements (WRM) are normally performed for every tap the same way as WRM for individual windings. The test instrument is continuously injecting test current and the resistances for each tap are measured sequentially as the tap changer is stepped through its positions. Results are typically presented as a graph or table with resistance values for each tap. Resistance changes between taps should be consistent with only small

deviations between different tap position changes.

2- Dynamic measurements

There are several methods developed for testing tap changers but common for all are that a current is injected in the tap changer, either in one phase or all phases, and during the operation of the tap changer, the current and/or the voltage is measured as a function of time. Test current vary from about 0.1 A to standard test current for winding resistance measurements, typically 1% of rated current for the transformer winding. The test may be performed at the same time as measuring winding resistance or as a separate test. Standard methods are;

- Discontinuity detection
- Dynamic current measurement (”ripple”)
- Dynamic resistance measurement

Discontinuity detection:

This method should detect if there is a break-before-make condition in the tap changer by monitoring current change. The measurement is typically performed at the same time as winding resistance measurements and the instrument detects if the contact switching is continuous or if there is an interruption in the current path.

Open contact detection can be made by current change detection, detecting dI/dt changes or detecting voltage change on the opposite side of the transformer i.e. if the tap changer is on the HV side, the detection is performed by measuring voltage transients on the corresponding LV winding.

Methods for contact timing based on current change detection are principally pending test current. If the test is performed at a current level where the inductance is high, the inductance in the transformer winding smooths the current change. If the test is performed at a current level at or above saturation level, the inductance is low and current level change will be higher and with longer duration**.**

Dynamic current measurement

Dynamic current measurement is in a way similar to discontinuity testing but in addition to just detecting discontinuity, the actual test current is measured and the result is presented as a percentage ripple value or more detailed in a current-time diagram. The intention is to give a value that describes the conditions during operation and provide contact timing.

Dynamic current measurements are also pending test current and inductance of the circuit in the same way as detecting discontinuity with current change detection. A method to reduce transformer inductance when performing dynamic measurements is to short-circuit the not tested corresponding LV (or HV) windings. This action is principally

“replacing” the inductance of the winding with the short-circuit impedance. Inductance is greatly reduced and contact timing can be measured with higher accuracy.

Dynamic resistance measurement

Dynamic resistance measurement (DRM) is a standard method for circuit-breaker testing and can also be applied on tap changer contacts. A relatively small and constant test current is injected through the tap changer and the voltage over the test circuit is measured with sufficient resolution to create a resistance versus time diagram for the LTC contact operation. Interruptions are easily recognized and irregularities in the diverter resistor values can be measured. DRM testing is usually combined with short-circuiting corresponding winding to reduce influence of inductance.

Using MTO for tap changer measurements

The MTO210 and 3xx are designed for LTC testing with the instrument left ON while changing from tap to tap and secondary windings of the transformer NOT short-circuited. This allows the operator to take measurements very quickly without discharging the transformer for every tap. A current change larger than 10% (10% current drop) is detected and may be categorized as by the setting of the instrument.

0 – OFF (default, > 200 ms detection) 1 – > 80 msec detection 2 – > 20 msec detection 3 – > 5 msec detection

If the tap change causes a current change > 10% lasting shorter than the time setting, the unit will indicate and record the event but not stop the test. If the current change is longer than the setting, the unit will record the event and shut down the test. If the current is completely interrupted in a high inductance circuit, the unit will record the event and shut down the test irrespective of the current change detection setting (also in default/“OFF” setting).

As stated previously, “current change/ripple” is pending test current, contact timing and inductance of the winding. This is important to understand when analysing test results.

OLTC testing is typically performed as a winding resistance test but results are taken sequentially and indications of discontinuity are monitored. Test current for HV winding resistance measurements are often around saturation level or higher, where the inductance is low. This way of testing may give “high” current change/ripple even for “good” contacts. For continuity testing during standard WRM/tap, measurements at lower current (higher inductance) should be considered (more similar to normal working conditions of the transformer).

https://www.youtube.com/watch?v=QKz7YL0Gv7k

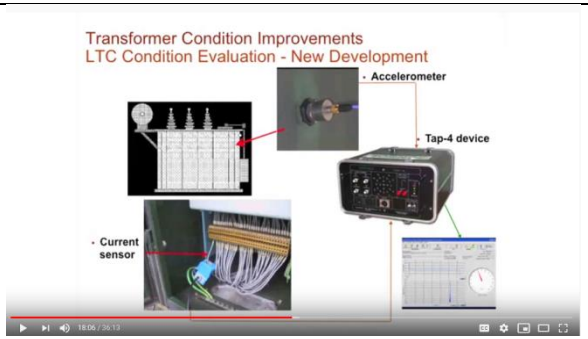
You can see how these tests are informed by using the above website address

Replacement of faulty transformer tap changer

To replace the faulty tap changer following procedure should be adopted;

1- Isolate transformer from electrical supply & tag properly
2- Open the upper cover plate of transformer
3- Remove transformer oil from tank up to required level
4- Un braze the terminals of tap changer and tags them accordingly
5- Un bolt tap changer and remove it from transformer tank
6- Got new tap changer and observe its working and put it in transformer tanks
7- Fit the tap changer
8- Braze its connection terminals one by one after matching its tags
9- Refill transformer oil up to required level
10- Put new gas kit and refit the upper cover plate of transformer
11- Remove tags and ON the supply

You can observe the replacement of faulty transformer tap changer be using the given below website address



https://www.youtube.com/watch?v=A2RlD1Amyvs

State method of updating the record

Update the record regarding checking, cleaning & replacement of transformer tap changer; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record this in history sheet of transformer.

LU8. Check main Tank body of Transformer for leakage

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe procedure for:**

Physical checking of transformer tank

The function of the tank in the transformer is to be a container for the oil used in it. The oil in the tank is used for insulation and cooling. The tank can also be used as a support for other equipment's of the transformer. The fault in the tank occurs due to environmental stress, corrosion, high humidity and sun radiation resulting in a leakage or cracks in the tank walls. From these leakages and cracks oil spill from the tank causing the reduction of oil;

A. The reduction in oil level results in the reduction of insulation in the transformer and affecting the windings.

B. The oil is also used for cooling purposes so the reduction of oil causes over-heating with damages different parts of the transformer.

Early identification and rectification of a leaking transformer can save a potential environmental hazard with leaking oils making their way into soils, ground water, streams and storm water. Even if your transformer is located far inland and away from any obvious waterways, the oil can still contaminate the groundwater. Failing to staunch the leak and clean up the oil, then, can lead to environmental issues and consequences with government agencies.

Quick transformer repair is also important to protect the transformer itself. When there is a hole somewhere in your

transformer, you shouldn't just be concerned about what is getting out. On the contrary, you also need to think about what is getting in. A breach provides a place for rainwater or other moisture to get into your transformer and impair its performance. Indeed, water can even lead to the failure of your transformer. Getting a quick transformer oil leak repair, then, is vital to protect your transformer and avoid more costly repairs (or outage time) further on down the road.

Locating of leakage point in transformer tank

Most oil losses occur from rusting. You can see where the oil leaks but finding the hole may be more difficult. It may be that the seam is very thin in many places. Cleaning the area thoroughly &locate the proper place of leakage. Even slight oil leaks, creating stains down the sides of transformers, create a negative perception to the general public that the utility is not maintaining their equipment to a high standard of reliability. Oil stain can run down the side of a large high voltage power transformer, while oil leaks and stains at the base flange of high voltage bushing pockets. Oil leak quantities can be great enough to require the use of absorbent material in granular form, or in rectangular oil absorbent pads to contain an oil release to keep it from running into the substation drainage system and potentially running off the station property into the general environment outside the station.

Draining out oil from transformer tank

The classic repair technique is to take the transformer out of service, drain the oil, remove radiators, remove bushings, etc. Taking equipment out of service for weeks at a time, and utilizing large substation crews, cranes, tankers, vacuum fill-oil processing trailers, etc. can be a costly endeavor. Today's electric utility management is monitoring expenses closely. Transmission operations are wheeling power from far away generation sources to the local utility distribution load centers. Outages on transmission equipment are closely scheduled, and lengthy outages are not granted on short notice for emergent repairs. The operations staff is coming to the maintenance staff asking for other solutions to address these oil leak repairs. Using epoxy resin will work as an emergency measure but don't trust it for long. Poly water's Power Patch, a powerful transformer putty and sealant that can stop active leaks. More than just a temporary fix, this duct sealant uses a two-part paste to create a permanent seal in the body of your transformer.

Welding of transformer tank

The ultimate solution of repair is welding of transformer tank. For welding following procedure should be observed.

1- Mark the located point of oil leakage
2- Set the value of current on welding transformer according to gauge of transformer body plates.
3- Perform welding
4- Inspect the welded point by enlarging lens
5- Paint the welded place

Refilling of transformer oil in tank

After repair work of transformer tank, transformer oil is refilled using the method discussed earlier.

Final checking of leakage point

After refilling transformer tank with transformer oil, final checking of oil leakage should be carried out

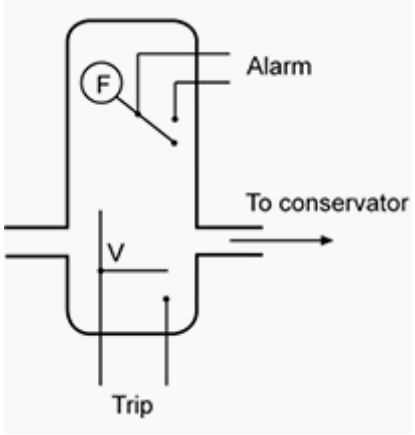
State method of updating the record

Update the record regarding checking, cleaning &repairing tank of transformer; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record this in history sheet of transformer.

LU9. Repair/Replace Buchholz Relay

- **Demonstration regarding selection & use of required Tools, equipment & PPEs**
- **Describe Working principle and possible faults of Buchholz relay**

The Buchholz relay working principle is based on very simple mechanical phenomenon. It is mechanically actuated. Whenever there will be a minor internal fault in the transformer such as an insulation faults between turns, break down of core of transformer, core heating, the transformer insulating oil will be decomposed in different hydrocarbon gases, CO_2 and CO. The gases produced due to decomposition of transformer insulating oil will accumulate in the upper part the Buchholz container which causes fall of oil level in it.A typical Buchholz protection comprises a pivoted float (F) and a pivoted vane (V) as shown in Figure. The float carries one mercury switch and the vane also carries another mercury switch. Normally, the casing is filled with oil and the mercury switches are open.



When minor fault occurs within the transformer the gases produced by minor faults rise from the fault location to the top of the transformer. Then the gas bubbles pass up the piping to the conservator. The gas bubbles will be tapped in the casing of the Buchholz protection. This means that the gas replaces the oil in the casing. As the oil level falls, the float (F) will follow and the mercury switch tilts and closes an alarm circuit.

If a major fault, either to earth of between phases or windings, occurs within the transformer, then such faults rapidly produce large volumes of gas (more than 50 cm3 / (KWs) and oil vapor which cannot escape. They therefore produce a steep buildup of pressure and displace oil. This sets up a rapid flow from the transformer towards the conservator. The vane (V) responds to high oil and gas flow in the pipe to the conservator. In this case, the mercury switch closes a trip circuit. The operating time of the trip contact depends on the location of the fault and the magnitude of the fault current. The operating time should not exceed 0.3 seconds.

The gas accumulator relay also provides a long-term accumulation of gasses associated with overheating of various parts of the transformer conductor and insulation systems. This will detect fault sources in their early stages and prevent significant damage.

When the transformer is first put into service, the air trapped in the windings may give unnecessary alarm signals. It is customary to remove the air in the power transformers by vacuum treatment during the filling of the transformer tank with oil.

The gas accumulated without this treatment will, of course, be air, which can be confirmed by seeing that it is not

inflammable. In addition, the Buchholz relay can detect if the oil level falls below that of the relay as a result of a leakage from the transformer tank. The video below shows a working animation of a Buchholz relay. You can the animation by uploading website address shown below.

https://www.youtube.com/watch?v=qhl5ZEKegXc

Describe procedure for:

Checking of Buchholz relay

Buchholz protection is a protective device that is sensitive to dielectric faults in the transformer. Overheating of the relay occurs because of accumulation of gasses over time, which reduces its sensitivity to dielectric faults. Low level oil due to leakage causes the Buchholz protection to come into action even if there is not a fault which is not needed and waste of energy.

Replacement of Buchholz relay

To replace a Buchholz relay you should observe the following procedure;

1- Isolate transformer from supply
2- Release pressure by opening the valve connected to Buchholz relay
3- Un bolt the relay from both sides
4- Remove Buchholz relay
5- Fit new relay
6- Ensure proper tightening of bolts
7- Switch ON supply of transformer

You can see the video of Buchholz relay replacement by using the website address given below

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-C
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https://www.youtube.com/watch?v=QAByqA_AeUQ

State method of updating the record

Update the record regarding checking & replacement of transformer Buchholz relay; this will helps you to add this in bill claim in case when you are doing this in your repair workshop. In case when you are working in industry record this in history sheet of transformer.

Module C: Contribute to Work Related Health and Safety (WHS) Initiatives.

Objective:

Duration: 30 Hours **Theory: 6 Hours** **Practice: 24 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Contribute to initiate work-related health and safety measures			
LU2. Contribute to establish work-related health and safety measures			
LU3. Contribute to ensure legal requirements of WHS measures			
LU4. Contribute to review WHS measures			
LU5. Evaluate the organization's WHS system			

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-D

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module D: Analyse Workplace Policy and Procedures

Objective:

Duration: 30 Hours **Theory: 6 Hours** **Practice: 24 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Manage work timeframes			
LU2. Manage to convene meeting			
LU3. Decision making at workplace			
LU4. Set and meet own work priorities at instant			
LU5. Develop and maintain professional competence			
LU6. Follow and implement work safety requirements			

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-E

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module E: Perform Advanced Communication

Objective:

.

Duration: 30 Hours **Theory: 6 Hours** **Practice: 24 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Demonstrate professional skills			
LU2. Plan and Organize work			
LU3. Provide trainings at workplace			

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-F

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module F: Develop Advance Computer Application Skills

Objective:

Duration: 40 Hours **Theory: 8 Hours** **Practice: 32 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Manage Information System to complete a task			
LU2. Prepare Presentation using computers			
LU3. Use Microsoft Access to manage database			
LU4. Develop graphics for Design			

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-G

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module G: Manage Human Resource Services

Objective:

Duration: 20Hours **Theory: 4 Hours** **Practice: 16 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Determine strategies for delivery of human resource services			
LU2. Manage the delivery of human resource services			
LU3. Evaluate human resource service delivery			
LU4. Manage integration of business ethics in human resource practices			

ELECTRICAL MACHINE WINDING TECHNICIAN

Module-H

LEARNER GUIDE

National Vocational Certificate Level 4

Version 1 - September, 2018

Module H: Develop Entrepreneurial Skills

Objective:

Duration: 30 Hours **Theory: 6 Hours** **Practice:24 Hours**

Learning Unit	Learning Outcomes	Learning Elements	Materials Required
LU1. Develop a business plan			
LU2. Collect information regarding funding sources			
LU3. Develop a marketing plan			
LU4. Develop basic business communication skills			

Summary of Module

Module	Learning Unit	Duration
○ **Module A:** Repair / Replace Allied parts of Machine (Motor). **Aim:** The aim of this module is to develop basic knowledge, skills and understanding required for Repair / Replacement of Allied parts like Bearing, Bush ,Carbon Brushes, Commutator / Slip rings, Rotor ant its Shaft, Centrifugal Switch (Clutch), Capacitor and terminals of Motor	**LU1. Prepare for work to repair / replace allied parts of machine (Motor)** **LU2.** Replace Bearing **LU3.** Replace Bush **LU4.** Replace Carbon Brushes **LU5.** Repair/Replace Commutator / Slip rings **LU6.** Check Rotor ant its Shaft **LU7.** Repair/Replace Centrifugal Switch (Clutch) of Motor **LU8.** Replace Capacitor of Motor **LU9.** Repair/Replace terminals of Motor	120 hours

Module	Learning Unit	Duration
○ **Module B:** Repair / replace allied parts of machine (Transformer) **Aim:** The aim of this module is to develop basic knowledge, skills and understanding required for Repair / Replacement of Allied parts like filtration & de-hydration of Transformer oil , De- Hydration of Silica Gel, Transformer Bushings, Tap Changer and Buchholz Relay of transformer.	**LU1.** **Prepare for work** to repair / replace allied parts of machine (Transformer) **LU2.** Collect the required materials/parts **LU3.** Perform filtration & de-hydration of Transformer oil **LU4.** Replace Transformer Oil **LU5.** Perform De- Hydration of Silica Gel **LU6.** Repair / Replace Transformer Bushings **LU7.** Repair/ Replace Tap Changer **LU8.** Check main Tank body of Transformer for leakage **LU9.** Repair/Replace Buchholz Relay	90

Module	Learning Unit	Duration
Module C: Contribute to Work Related Health and Safety (WHS) Initiatives **Aim:** The aim of this module is to develop basic knowledge, skills and understanding to contribute towards initiation, establishment and ensuring work related health and safety measures and evaluation of the organization's WHS System as well	**LU1. Contribute to initiate work-related health and safety measures** **LU2. Contribute to establish work-related health and safety measures** **LU3. Contribute to ensure legal requirements of WHS measures** **LU4. Contribute to review WHS measures** **LU5. Evaluate the organization's WHS system**	30
Module D: Analyse Workplace Policy and Procedures **Aim:** The aim of this module is to develop basic knowledge, skills and understanding to Manage work timeframes, convene meeting, Set and meet own work priorities, Develop and maintain professional competence and Follow and implement work safety requirements	**LU1. Manage work timeframes** **LU2. Manage to convene meeting** **LU3. Decision making at workplace** **LU4. Set and meet own work priorities at instant** **LU5. Develop and maintain professional competence** **LU6. Follow and implement work safety requirements**	30
Module E: Perform Advanced Communication **Aim:** The aim of this module is to develop basic knowledge, skills and understanding to perform advanced communication	**LU1. Demonstrate professional skills** **LU2. Plan and Organize work** **LU3. Provide trainings at workplace**	30

Module	Learning Unit	Duration
Module F: Develop Advance Computer Application Skills **Aim:** The aim of this module is to develop basic knowledge, skills and understanding required to Manage Information System, Prepare Presentation, manage database and Develop graphics for Design.	**LU1. Manage Information System to complete a task** **LU2. Prepare Presentation using computers** **LU3. Use Microsoft Access to manage database** **LU4. Develop graphics for Design**	40
Module G: Manage Human Resource **Aim:** The aim of this module is to develop basic knowledge, skills and understanding to Manage Human Resource through Determine strategies for delivery of human resource services, manage delivery , evaluation and integration of business ethics in human resource services.	**LU1. Determine strategies for delivery of human resource services** **LU2. Manage the delivery of human resource services** **LU3. Evaluate human resource service delivery** **LU4. Manage integration of business ethics in human resource practices**	20 hours

Module	Learning Unit	Duration
Module H: Develop Entrepreneurial Skills **Aim:** The aim of this module is to develop basic knowledge, skills and understanding to Develop Entrepreneurial Skills which are essential for seeking self employment.	**LU1. Develop a business plan** **LU2. Collect information regarding funding sources** **LU3. Develop a marketing plan** **LU4. Develop basic business communication skills**	30 hours

Test Yourself (Multiple Choice Questions)

Level 4

MOTOR PARTS REPLACEMENT

Q 1: Which device is used to reverse current after every half turn in DC motor?

a) Carbon brush
b) Commutator
c) Slip-ring
d) Carbon spring

Q 2: A magnet may attract or repel:

a) Another magnet
b) Electric current
c) Resistor
d) Capacitor

Q 3: Electric motor changes electrical energy into:

a) Potential energy
b) Thermal energy
c) Heat energy
d) Kinetic energy

Q 4: Many machines we use, are powered by:

a) Thermal energy
b) Sound energy
c) Electric motors
d) Dynamos

Q 5: Magnetic field of coil is controlled with?

a) Adding variable Resistance in parallel
b) Adding variable Capacitance in parallel
c) Adding variable Resistance in series
d) Adding variable Capacitance in series

Q6: The frame of an induction motor is usually made of:

a) Silicon steel
b) Cast iron

c) Aluminium
d) Bronze

Q7:The shaft of an induction motor is made up of:

a) Stainless steel
b) Cast iron
c) Aluminium
d) Carbon steel

Q8: What will be the equivalent capacitance (in mF) of three capacitors connected in a series having the capacitance of 0.04 mF, 0.08 mF, and 0.02 mF respectively?

a) 0.026 **mF**
b) 0.032 **mF**
c) 0.065 **mF**
d) 0.011 **mF**

Q9: Which one of the following is the mathematical expression of the Ohm's Law?

a) V = I……
b) V = R/I
c) V = I.R
d) V = R

Q10: A 50 Hz, 3-phase induction motor has a full load speed of 1440 r.p.m. The number of poles in the motor are:

a) 2 pole
b) 4 pole
c) 6 pole
d) 8 pole

Q11: What will happen If any two phases for an induction motor are interchanged?

a) The motor will stop
b) The motor will continue to run in the same direction
c) The motor will Burn

d) The motor will run in reverse direction

Q12: In three-phase squirrel-cage induction motors:

a) Rotor conductors are short-circuited through end rings
b) Rotor conductors are kept open
c) Rotor conductor ends are short-circuited through slip rings
d) Rotor conductors are connected to insulation

Q13: In a three-phase induction motor, the number of poles in the rotor winding is always:

a) Equal to number of poles in stator
b) More than the number of poles in stator
c) Zero
d) Less than the number of poles in stator

Q14: As compared to DOL starting method, the star delta starting method should have:

a) High torque
b) Low starting current
c) High starting current
d) Smooth acceleration

Q15: In a split phase motor, the running winding should have:

a) High resistance and low inductance
b) High resistance and High inductance
c) Low resistance and high inductance
d) Low resistance and Low inductance

Q16: What will happen If the capacitor of a single-phase motor is short-circuited?

a) The motor will not start
b) The motor will run in the same direction at reduced speed
c) The motor will run in reverse direction
d) None of the above

Q17: In a split phase motor:

a) Both starting and running windings are connected through a centrifugal switch
b) Centrifugal switch is used to control supply voltage
c) The running winding is connected through a centrifugal switch
d) The starting winding is connected through a centrifugal switch

Q18: In a capacitor start and run motors the function of the running capacitor in series with the auxiliary winding is to:

a) Improve torque
b) Improve power factor
c) Reduce fluctuations in torque
d) Increase overload capacity

Q19: A centrifugal switch is used to disconnect 'starting winding when motor has:

a) Picked up 50 – 70% speed
b) Picked up 10% speed
c) Picked up 20% speed
d) Picked up 5 – 10% speed

Q20: **Which of the following motor is used in the mixer?**

a) Repulsion Motor
b) Reluctance Motor
c) Hysteresis Motor
d) Universal Motor

Answers Key	
Number	**Correct Answer**
1	**b**
2	**a**
3	**d**
4	**c**
5	**c**
6	**b**
7	**d**
8	**b**

9	**c**
10	**c**
11	**d**
12	**a**
13	**c**
14	**b**
15	**c**
16	**a**
17	**d**
18	**b**
19	**a**
20	**d**

Transformer Parts Replacement

Please mark the correct one from the given options.

Q 1: What is the function of Transformer oil used in transformer?

a) Insulation and cooling
b)Cooling and lubrication
c) Lubrication and insulation
d) Insulation, cooling and lubrication

Q2: Which should not be present in transformer oil?

a)Sulphur
b)Odor
c)moisture
d)both(a) and (c)

Q3:Transformer core is made up of :

a) Alumimium
b) Silicon steel
c) Copper
d) Cast Iron

Q4: Which of the following is minimized by laminating the core of a transformer?
a) Hysteresis loss
b) Eddy current loss
c) Heat loss
d) All of these
Q5:What is the size of thickness of laminations of transformer core?
a) 0.35 mm to 0.5 mm
b) 3.5 mm to 5 mm
c) 35 mm to 50 mm
d) 5mm to 10 mm
Q6:What factors determine the size of transformer core?
a) Area of the core
b) Flux density of core material
c) Frequency
d) Both (b) and (c)
Q7:What is the function of breather In power transformers?
a) Provide insulation to the windings
b) Provide cooling to the windings
c) Take insulating oil from the conservator
d) Extract moisture from the air
Q8:What is meant by conservator in a transformer?
a) Drum placed at the bottom of the tank
b) An air tight metal drum fixed at the top of the tank
c) Overload protection circuit
d) None of these
Q9:What should be the value of resistance between primary and secondary winding of transformer?
a) Infinite
b) Zero
c) About 1 MΩ

d) About 100 MΩ

Q10:What type of core section is best for utilization of available core space in power transformer?

a) Square core section
b) Stepped core section
c) Rectangular core section
d) Triangular core section

Q11:What is the advantage of Five limb core construction over three limb core construction of transformer?

a) Hysteresis loss is less
b) Permeability is higher
c) Magnetic reluctance of the three phases can be balanced
d) Eddy current loss is less

Q12:What is reduced in a transformer, when low voltage windings are placed nearer to the core in concentric winding?

a) Eddy current loss
b) Insulation requirement
c) Leakage fluxes
d) Hysteresis loss

Q13: Why Transformer windings are tapped in the middle?

a) It eliminates axial forces on the windings
b) It eliminates radial forces on the windings
c) It reduces insulation requirement
d) None of these

Q14: Which of the following materials is used to absorb moisture from air entering the transformer?

a) Silica sand
b) Silica gel
c) Felt pad
d) Sodium chloride

Q15: Which of the following acts as a protection against high voltage surges due to lightening and switching?

a) Horn gaps
b) Thermal overload relays
c) Conservator
d) Breather

Q16: What is the function of tap changer in a transformer?

a) Adjustment in power factor
b) Adjustment in secondary voltage
c) Adjustment in primary voltage
d) Adjustments in both primary and secondary voltage

Q17:What is the effect of over current in a transformer?

a) Insulation life
b) Temperature rise
c) Mechanical stress
d) All of these

Q18:Highest rating transformers are likely to be used in:

a) Generation
b) Transmission
c) Distribution
d) Substation

Q19: Transformer ratings are usually expressed in terms of:

a) Voltage
b) KVA
c) KWh
d) KW

Q20: What is the name of noise in transformer due to vibration of laminations set by magnetic forces?

a) Flicker noise
b) Transit-time noise
c) Agitation noise
d) Humming noise

Answer Key	
Number	**Correct Answer**
1	**a**
2	**d**

3	**b**
4	**b**
5	**a**
6	**d**
7	**d**
8	**b**
9	**a**
10	**b**
11	**c**
12	**b**
13	**a**
14	**b**
15	**a**
16	**b**
17	**d**
18	**a**
19	**b**
20	**d**

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